Research Article

International Journal of Agriculture and Wildlife Science
Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi
2024, 10(2): 216 – 224, doi: 10.24180/ijaws.1421481

Comparison of Performance Characteristics of Different Types of Hazelnut Harvesting Machines*

Farklı Tip Fındık Toplama Makinalarının Performans Karakteristiklerinin Karşılaştırılması

Hüseyin Sauk[1], Mehmet Arif Beyhan[2]

Received: 14.01.2024 **Accepted:** 17.04.2024 **Published:** 25.08.2024

Abstract: In this study, the possibilities of using the hazelnut harvesting machine with pneumatic effective harvesting unit produced by local manufacturers and the prototype manufactured hazelnut harvesting machine with mechanical effective harvesting unit in the mechanical harvesting of hazelnuts grown in flat and near flat land conditions were examined, some performance values (harvesting efficiency, labor requirement, machine+human labor requirement, field productivity, machine+human field productivity and kernel productivity) of hazelnut harvesting machines with mechanically operated harvesting units were determined under different orchard yield conditions. According to the results of the experiment, the hazelnut harvesting machine with a mechanical effective harvesting unit had a harvesting efficiency of 92.54-96.03% and; a labor requirement of 6.349-9.839 MİGh ha^{-1}; machine+human labor requirement of 46.228-62.531 BİİGh ha^{-1}; field productivity 0.158-0.102 ha $MİGh^{-1}$; machine+human field productivity: 0.022-0.016 ha $BİİGh^{-1}$; kernel productivity: 124.83-1322.08 kg h^{-1}. The hazelnut harvesting machine with a pneumatic effective harvesting unit has a harvesting efficiency of 97.68-99.36%; labor requirement 70.349-105.647 BİİGh ha^{-1}; machine+human labor requirement 108.509-147.481 BİİGh ha^{-1}; field productivity 0.014-0.009 ha $MİGh^{-1}$; machine+human field productivity 0.009-0.007 ha $BİİGh^{-1}$; kernel productivity 18.90-67.18 kg h^{-1}. As a result, when the characteristics of harvesting efficiency, field productivity, and kernel productivity of the machines are compared, the mass production of hazelnut harvesting machines with mechanically effective harvesting units can provide benefits for hazelnut producers in terms of reducing harvesting costs and demand for labor.

Keywords: Labor requirement, field productivity, kernel productivity

&

Öz: Bu çalışmada, yerel imalatçılar tarafından üretilen pnömatik etkili toplama üniteli fındık toplama makinası ile prototip imalatı yapılmış mekanik etkili toplama üniteli fındık toplama makinasının düz ve düze yakın arazi koşullarında yetiştirilen fındığın mekanik hasadında kullanılma olanaklarını incelenmiş olup, farklı bahçe verim koşullarında mekanik etkili toplama üniteli fındık toplama makinalarının bazı performans değerleri (toplama etkinliği, iş gücü gereksinimi, makina+insan iş gücü gereksinimi, alan iş başarısı, makina+insan alan iş başarısı ve ürün iş başarısı) belirlenmiştir. Deneme sonuçlarına göre, mekanik etkili toplama üniteli fındık toplama makinasının, toplama etkinliği %92.54-96.03; iş gücü gereksinimi 6.349-9.839 MİGh ha^{-1}; makina+insan iş gücü gereksinimi 46.228-62.531 BİİGh ha^{-1}; alan iş başarısı 0.158-0.102 ha $MİGh^{-1}$; makina+insan alan iş başarısı: 0.022-0.016 ha $BİİGh^{-1}$; ürün iş başarısı: 124.83-1322.08 kg h^{-1} olarak tespit edilmiştir. Pnömatik etkili toplama üniteli fındık toplama makinasının ise toplama etkinliği %97.68-99.36; iş gücü gereksinimi 70.349-105.647 MİGh ha^{-1}; makina+insan iş gücü gereksinimi 108.509-147.481 BİİGh ha^{-1}; alan iş başarısı 0.014-0.009 ha $MİGh^{-1}$; makina+insan alan iş başarısı 0.009-0.007 ha $BİİGh^{-1}$; ürün iş başarısı 18.90-67.18 kg h^{-1} olarak saplanmıştır. Sonuç olarak, makinaların toplama etkinliği, alan iş başarısı ve ürün iş başarısı karakteristikleri karşılaştırıldığında, mekanik etkili toplama üniteli fındık toplama makinasının seri imalatı yapıldığında, fındık üreticileri için hasat maliyeti ve işçiye olan talebi azaltması açısından yararlar sağlayabilecektir.

Anahtar Kelimeler: İşgücü gereksinimi, alan iş başarısı, ürün iş başarısı

Cite as: Sauk, H., & Beyhan M. A., (2024). Comparison of performance characteristics of different types of hazelnut harvesting machines. International Journal of Agriculture and Wildlife Science, 10(2), 216-224. doi: 10.24180/ijaws.1421481

Plagiarism/Ethic: This article has been reviewed by at least two referees and it has been confirmed that it is plagiarism-free and complies with research and publication ethics. https://dergipark.org.tr/tr/pub/ijaws

[1] Dr. Öğr. Üyesi Hüseyin Sauk, Ondukuz Mayis University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, hsauk@omu.edu.tr (Corresponding author)

[2] Prof. Dr. Mehmet Arif Beyhan, Ondukuz Mayis University, Faculty of Agriculture, Department of Agricultural Machinery and Technologies Engineering, mabeyhan@omu.edu.tr

*This article is produced from Hüseyin SAUK's PhD thesis.

INTRODUCTION

Turkey has 74.50% of the world's hazelnut planting areas with an area of approximately 700 thousand ha. Hazelnuts in shell production is approximately 665 thousand tons and supply about 76% of the world's hazelnut production. Hazelnut exports are approximately 500 thousand tons and 75% of the world's hazelnut exports (Turkish Statistical Institute [TÜİK], 2023). Although Turkey is the world's leading producer and exporter of hazelnuts and the sole source of livelihood for around 500 thousand farmers, harvest mechanization has not reached the same level with competing countries. Hazelnut harvesting, which has an important place in the agriculture of our country, is done manually, but it is also done mechanically with the widespread use of hazelnut harvesting machines developed by local manufacturers recently (Beyhan and Sauk, 2018).

Harvesting in stone fruit production, due to high labor requirements, is an important factor in determining product cost (Tous et al., 1994). For example, hand-harvesting hazelnuts under Turkish conditions requires 306 BİİGh ha^{-1}. This account constitutes 71% of the total working time for production and 55% of the production cost (İlkyaz, 1986). This situation not only significantly increases the cost of hazelnut production but also causes labor-intensive labor requirements during the harvest period. Reducing the high labor requirement and cost is possible by mechanizing the harvesting process.

Hazelnut harvesting is fully mechanized in other economically producing countries except for Turkey. However, there are many factors affecting the feasibility of mechanical harvesting. The main factors are topography, soil properties, planting technique, garden size, variety characteristics, technical-cultural practices, and socio-economic status. Today, methods have been developed to eliminate the negative effects of many of these factors. As a result, differences have emerged in the mechanical harvesting technologies applied in different production regions around the world (Beyhan and Yıldız, 1996). In some important hazelnut producing countries such as the USA, Italy, France, and Spain, mechanical harvesting methods are applied to the extent that the land and planting technique allows. Machines with pneumatic and mechanical action have been developed for the harvesting of hazelnuts from the orchard ground in one or two operations (Zoppello and Tempia, 1988; Ghiotti, 1989). In Turkey, machine harvesting studies started with the trials of aspirated machines, the design and manufacture of which were carried out by Beyhan (1992). Beyhan (1992), designed and manufactured an aspiration hazelnut harvesting machine suitable for Turkish conditions. As a result of the experiments conducted under three different orchard yield conditions (113.4, 226.8, and 340.2 kg ha^{-1}), under the condition where the orchard yield was 226.8 kg ha^{-1}, kernel productivity, harvesting efficiency, and field productivity were determined as 28.48 kg h^{-1}, 95.13%, and 0.396 da h^{-1}, respectively. Since the machine was operated by three people, the kernel productivity per person reached its highest value at the maximum orchard yield.

On the other hand, all these operations can be performed by one person with machines with mechanical harvesting units. For these reasons, harvesting machines with mechanical harvesting units have started to be developed to increase harvesting efficiency and labor productivity, minimize production losses, cover the largest possible area, reduce the dust problem, and obtain good results even in gardens with uneven ground and to reduce the power requirement (Biondi et al., 1992; Ghiotti, 1989; Yıldız, 2000). Yıldız (2000), also designed and tested a prototype hazelnut harvesting machine with a tractor-operated mechanical ground harvesting unit. The trials were conducted under three different orchard yield conditions (75, 150, and 225 kg ha^{-1}), three different working velocities (1, 1.6, and 3.2 km h^{-1}), and four different harvesting system speeds (490, 430, 360, and 300 min^{-1}). In the orchard trials carried out; (225 kg ha^{-1} orchard yield, 3.2 km h^{-1} working velocity, and 430 min^{-1} harvesting system speed), harvesting efficiency and kernel productivity were determined as 91.66% and 100.29 kg ha^{-1}, respectively. In addition, it was reported that the field productivity of the machine was between 1-1.5 da h^{-1}, depending on the orchard yield. Monarca et al. (2005), in their studies on the developments in hazelnut harvesting machines, stated that with the increase in hazelnut planting areas in Italy in the last 20 years, manual harvesting has been replaced by machine harvesting, however, they stated that the product throughput increased from 100 kg h^{-1} to 1000 kg h^{-1} (about 10 times). They reported that the field productivity of hazelnut harvesters (trailed type and self-propelled type) varied between 0.2-0.4 ha h^{-1} and 0.35-5 ha h^{-1}, respectively. Monarca et al. (2008), In the study in which they compared the field productivity of hazelnut harvesting machines with different types of mechanical harvesting units, stated that the field productivity varied between 0.2-4 ha h^{-1} for trailed-type machines and 0.35-0.5 ha h^{-1} for self-propelled machines and that the field productivity of the machines varied depending on the working conditions, row length, and orchard structure.

Hazelnut harvesting machines with pneumatic effective harvesting unit (PHM) manufactured by local manufacturers and prototype manufactured hazelnut harvesting machines with mechanical effective harvesting unit (MHM), The possibilities of using in mechanical harvesting of hazelnut grown in flat and near flat land conditions will be examined and harvesting efficiency and work productivity will be determined. Data to be obtained as a result of the study, in addition to analyzing the mechanical harvesting of hazelnuts, will enable us to explain the reasons for the changes that may occur in the performance characteristics of the existing machines and to make suggestions for improvement. Thus, healthier recommendations will be made for the mechanical harvesting of hazelnuts grown on flat and nearly flat lands. A decrease in harvesting cost depending on the degree of mechanization of hazelnut harvesting, will increase our competitiveness in international markets. In addition, the results obtained will provide basic data for academic studies and applications in this field.

MATERIALS AND METHODS

Experimetal Desing

Harvesting experiments, it was carried out in a farmer's orchard in the Kızılot neighborhood of Çarşamba town of Samsun city. The hazelnut orchard where the trials were carried out has Çakıldak hazelnut variety, which is widely grown in the region. In five brushes (“ocak” in Turkish) to determine the distribution of naturally fallen hazelnuts around the ocak, squares of 1x1 m were formed from the base of the ocak to the outermost branch. The hazelnuts (kernel+husked hazelnut) within this field were harvested. The harvested hazelnuts were weighed and the hazelnut weight was determined.

In the orchard with an average row spacing of 4.55 m to determine the harvesting efficiency of hazelnut harvesting machines, experimental plots of approximately 20 m^2 were formed with each plot containing three ocak (Yıldız, 2000). Experimental plots were formed with dimensions of 1.60x12.50 m for PHM and 1.40x14.28 m for MHM. The harvesting trials were conducted as milling dry hazelnuts with 10% moisture content under orchard yield conditions of 71.74, 143.48, 215.23, 286.97, and 358.72 kg ha^{-1}, according to the random plot design with three replicates. For this purpose, 1.43, 2.86, 4.29, 5.72, 4.29, 5.72, and 7.15 kg hazelnuts were laid on the orchard ground considering the natural shedding conditions.

During the experiments, no intervention was made regarding the setting levels of PHM and MHM. PHM was operated at 2500 min^{-1} engine shaft speed, 3750 min^{-1} ventilator shaft speed, and 41.19 m s^{-1} transmission air velocity, while MHM was operated at 1.6 m s^{-1} working velocity.

Determination of Moisture Content

As the maturity periods of hazelnuts differ according to the varieties, hazelnuts of the same variety do not ripen at the same time. This causes the moisture content of the same variety of hazelnuts to be different during the harvest period. The sample hazelnuts were dried in an oven at 103 °C (±2 °C) until they reached constant weight. The samples taken from the oven were cooled in a desiccator and their dry weight was determined. Moisture content was determined using the following equation (Sauk, 2016)

$$Mouse(\%) = \frac{w0 - w}{w} x100 \tag{1}$$

where; w_0: wet weight of hazelnut (g); w: dry weight of hazelnut (g)

The last weights of the hazelnuts whose moisture contents were determined at these moisture levels were calculated with the equation given below.

$$Gs = \frac{Gb(100 - Øb)}{100 - Øs)} \tag{2}$$

where; G_s: weight of hazelnuts in dried form (kg); G_b: wet weight of hazelnut (kg); $Ø_b$: initial moisture content of the hazelnut (%); $Ø_s$: last moisture content of dried hazelnuts (%).

Determining the Harvesting Efficiency

Hazelnuts laid in the experimental plots were harvested separately by PHM and MHM. Then, the foreign materials (soil, grass, twigs, leaves, etc.) collected by the machines together with the kernel+husked hazelnuts were removed and the harvested kernel+husked hazelnuts were weighed. Hazelnut weight was harvested by the machine from the unit area (kernel+husked hazelnut), The harvesting efficiency was calculated by proportion to the weight of grain+husked hazelnut spilled on the parcel.

Determining Labor Force and Field Productivity

The values obtained as a result of the trials to determine the labor requirements and field productivity of hazelnut harvesting machines depending on the yield of the orchard, It was evaluated according to a standard plot measuring 66.67x150 m in 1 ha area (Caran, 1994).

To determine the field productivity of hazelnut harvesting machines, the basic time (BT, (h ha^{-1})) and auxiliary times (AT,(h ha^{-1})) (transition time (TT), preparation time (PT), supply and replenishment time (SRT), break time (BT) and rotation time (RT)) were measured for each process with a stopwatch. 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) (Yıldız, 2016).

$$PT = BT + AT \ldots\ldots\ldots.. (\frac{h}{ha}) \tag{3}$$

Effective working time (EWT) was calculated from the following equation (Yıldız, 2016).

$$EWT = PT + UTL \ldots\ldots\ldots\ldots (\frac{h}{ha}) \tag{4}$$

Unavoidable time loss (UTL) was determined as a percentage of the principal time obtained by adding basic and auxiliary time (Yıldız, 2016).

$$UTL = \frac{P}{100} xPT \tag{5}$$

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.

The utilization coefficient (UC) was calculated from the following equation using total time (Yıldız, 2016).

$$UC = \frac{BT}{EWT} x100 \ldots\ldots (\%) \tag{6}$$

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 (Yıldız, 2016).

$$WPA = \frac{1}{EWT} \ldots\ldots\ldots. (\frac{ha}{h}) \tag{7}$$

Determining Kernel Productivity

Hazelnuts laid in the experimental plots were harvested separately by PHM and MHM. Time measurements for each machine's harvesting trial were recorded with the help of a stopwatch. To determine the kernel productivity of the machines (KP), the kernel harvested per unit time (KH) was divided by harvesting time (t) (Yıldız, 2000).

$$KP = \frac{KH}{t} \ldots\ldots\ldots. (\frac{kg}{h}) \tag{8}$$

During the harvesting of hazelnuts with the PHM, as the transmission hose of the machine is moved along the ground, hazelnuts can be harvested at the base of the ocak and over the rows. Product losses in these fields are shown in the hazelnuts that could not be harvested in the area swept by the machine.

Evaluation of Data

The data obtained in the study were analyzed in the JUMP 5.0 statistical package program, according to the random plots experimental design, and compared with the Duncan test.

RESULTS AND DISCUSSION

Harvesting Efficiency

As a result of the experiments, the changes in the harvesting efficiency values obtained depending on the garden yield and hazelnut picking machines are given in Table 1. The results of the analysis of variance showed that these factors affected the harvesting efficiency at a statistically significant level ($P<0.05$). However, the effect of hazelnut harvesting machines on harvesting efficiency was at different levels depending on the orchard yield.

Table 1. Harvesting efficiency values of machines under different orchard yield conditions (%).
Çizelge 1. *Farklı bahçe verimi koşullarında, makinaların toplama etkinliği değerleri (%).*

Type of machine	Orchard yield (kg da^{-1})					Average
	71.74	**143.48**	**215.23**	**286.97**	**358.72**	
MHM	92.54 e	94.00 d	95.87 c	95.95 c	96.03 c	94.87
PHM	97.68 b	98.83 a	98.95 a	99.09 a	99.36 a	98.78
Average	95.11	96.41	97.41	97.52	97.69	

(There is no difference between the data shown with the same lowercase letter according to $P<0.05$)

As seen in Table 1, harvesting hazelnuts with MHM, with the increase in orchard yield from 71.74 kg ha^{-1} to 143.48 kg ha^{-1} and from 143.48 kg ha^{-1} to 215.23 kg ha^{-1}, the increase in the harvesting efficiency value caused a statistically significant change, while it did not cause a statistically significant change in all orchard yields above 215.23 kg ha^{-1}. Again, as seen in Table 1, harvesting hazelnuts with PHM, the increase in the orchard yield from 71.74 kg ha^{-1} to 143.48 kg ha^{-1} caused a statistically significant change in the harvesting efficiency value, while it did not cause a statistically significant change in all orchard yields above 143.48 kg ha^{-1}. In addition, for all orchard yields, there was a statistically significant change in harvesting efficiency values when hazelnuts were harvested with PHM instead of MHM.

Labor Force and Field Productivity

The field productivity of MHM and PHM obtained with the use of machine + human labor in inter-row harvesting depending on orchard yields are given in Figure 1, and the field productivity obtained with the use of only machine are given in Figure 2.

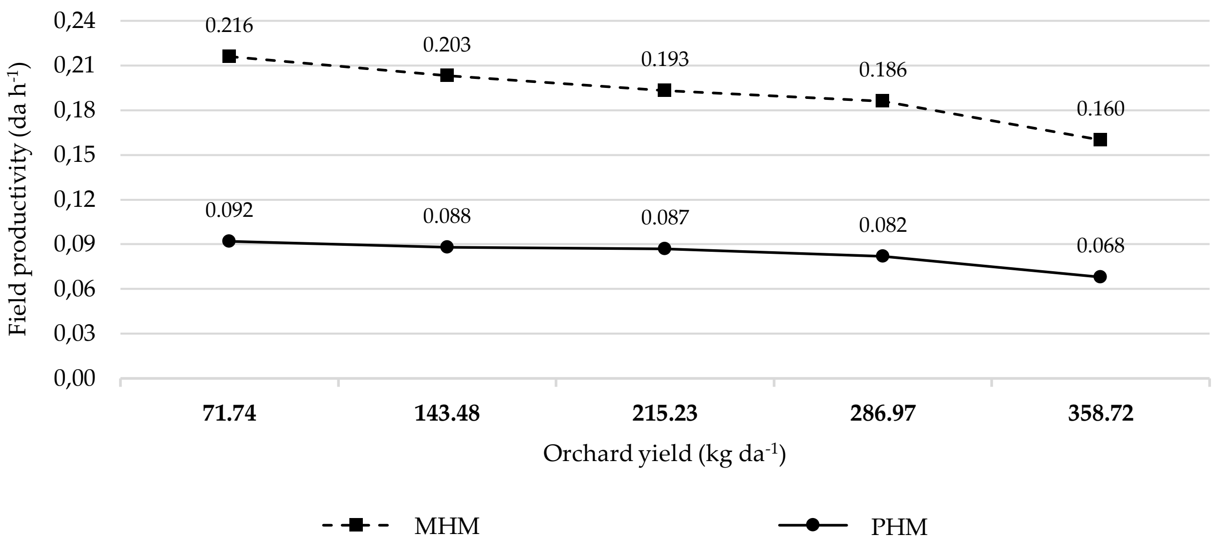

Figure 1. Field productivity values obtained by using machine+human labor.
Şekil 1. *Makina+insan iş gücü kullanımıyla elde edilen alan iş başarısı değerleri.*

As seen in Figure 1, the field productivity obtained with the use of PHM+human labor and MHM+human labor showed a decreasing trend in both machines due to the increase in orchard yield. The changes in field productivity were 0.092 da h^{-1} and 0.216 da h^{-1} for 71.74 kg ha^{-1}; 0.088 da h^{-1} and 0.203 da h^{-1} for 143.48 kg ha^{-1}; 0.087 da h^{-1} and 0.193 da h^{-1} for 215.23 kg ha^{-1}; 0.082 da h^{-1} and 0.186 da h^{-1} for 286.97 kg ha^{-1}; 0.068 da h^{-1} and 0.160 da h^{-1} for 358.72 kg ha^{-1}, respectively.

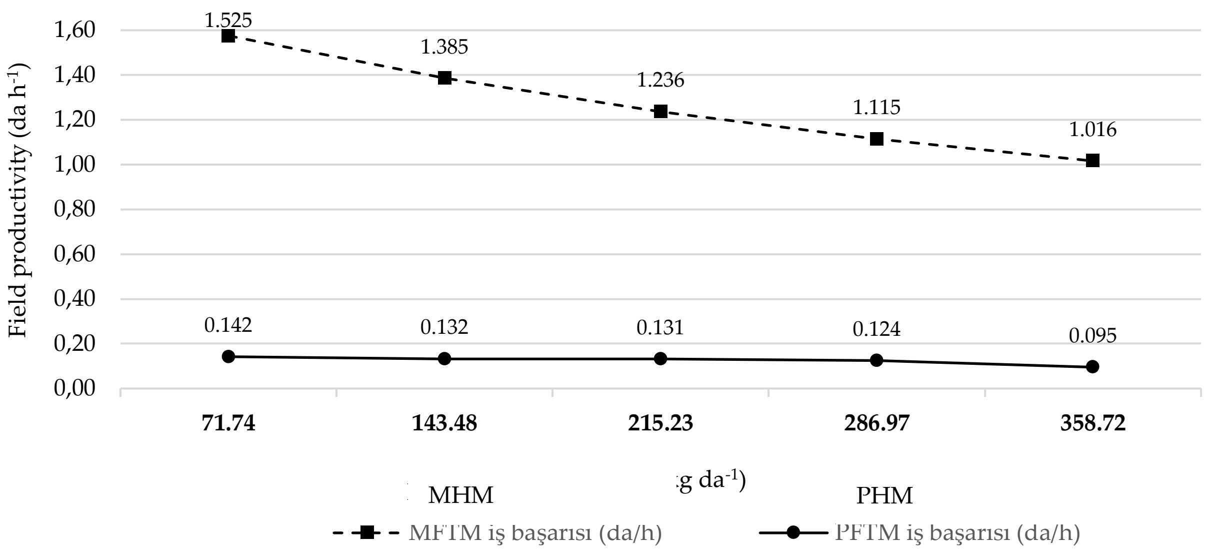

Figure 2. Field productivity values obtained by using machine labor.
Şekil 2. *Makina iş gücü kullanımıyla elde edilen alan iş başarısı değerleri.*

As seen in Figure 2, the field productivity obtained with the use of only MHM and PHM showed a decreasing trend depending on the increase in orchard yield. The changes in the field productivity of hazelnut harvesting machines depending on the orchard yield were found to be 0.142 da h^{-1} and 1.575 da h^{-1} for 71.74 kg ha^{-1}; 0.132 da h^{-1} and 1.385 da h^{-1} for 143.48 kg ha^{-1}; 0.131 da h^{-1} and 1.236 da h^{-1} for 215.23 kg ha^{-1}; 0.124 da h^{-1} and 1.115 da h^{-1} for 286.97 kg ha^{-1}; 0.095 da h^{-1} and 1.016 da h^{-1} for 358.72 kg ha^{-1}, respectively.

Depending on the increase in orchard yield, PHM+human labor requirement and PHM labor requirement are increasing. Accordingly, in the condition of 71.74 kg ha^{-1} orchard yield with PHM, the PHM+human labor requirement was 108.509 BİİGh ha^{-1}. In the same orchard yield condition, the hazelnuts within the ocak and the hazelnuts that could not be harvested by the machine were left not harvested, that is, only when the row spacing is harvested with the machine, PHM labor requirement is 70.394 MİGh ha^{-1}. If the orchard yield is 143.48, 215.23, 286.97, and 358.72 kg da^{-1}, change in PHM+human labor and PHM labor requirements, for 143.48 kg da^{-1}, 113.691 BİİGh ha^{-1} and 75.715 MİGh ha^{-1}; for 215.23 kg da^{-1}, 114.581 BİİGh ha^{-1} and 76.428 MİGh ha^{-1}; for 286.97 kg da^{-1}, 122.315 BİİGh ha^{-1} and 80.957 MİGh ha^{-1}; for 358.72 kg da^{-1}, 147.481 BİİGh ha^{-1} and 105.647 MİGh ha^{-1}, respectively.

Depending on the increase in orchard yield, MHM+human labor requirement and MHM labor requirement are increasing. Accordingly, in the condition of 71.74 kg ha^{-1} orchard yield with MHM, the MHM+human labor requirement was 46.228 BİİGh ha^{-1}. In the same orchard yield condition, the hazelnuts within the ocak and the hazelnuts that could not be harvested by the machine were left not harvested, that is, only when the row spacing is harvested with the machine, MHM labor requirement is 6.349 MİGh/ha. If the orchard yield is 143.48, 215.23, 286.97, and 358.72 kg da^{-1}, change in MHM+human labor and MHM labor requirements, for 143.48 kg da^{-1}, 49.182 BİİGh ha^{-1} and 7.221 MİGh ha^{-1}; for 215.23 kg da^{-1}, 51.711 BİİGh ha^{-1} and 8.094 MİGh ha^{-1}; for 286.97 kg da^{-1}, 53.783 BİİGh ha^{-1} and 8.966 MİGh ha^{-1}; for 358.72 kg da^{-1}, 62.531 BİİGh ha^{-1} and 9.839 MİGh ha^{-1}, respectively.

Kernel productivity

Kernel productivity values for milling dry hazelnuts (10% moisture) obtained as a result of the trials are given in Figure 3.

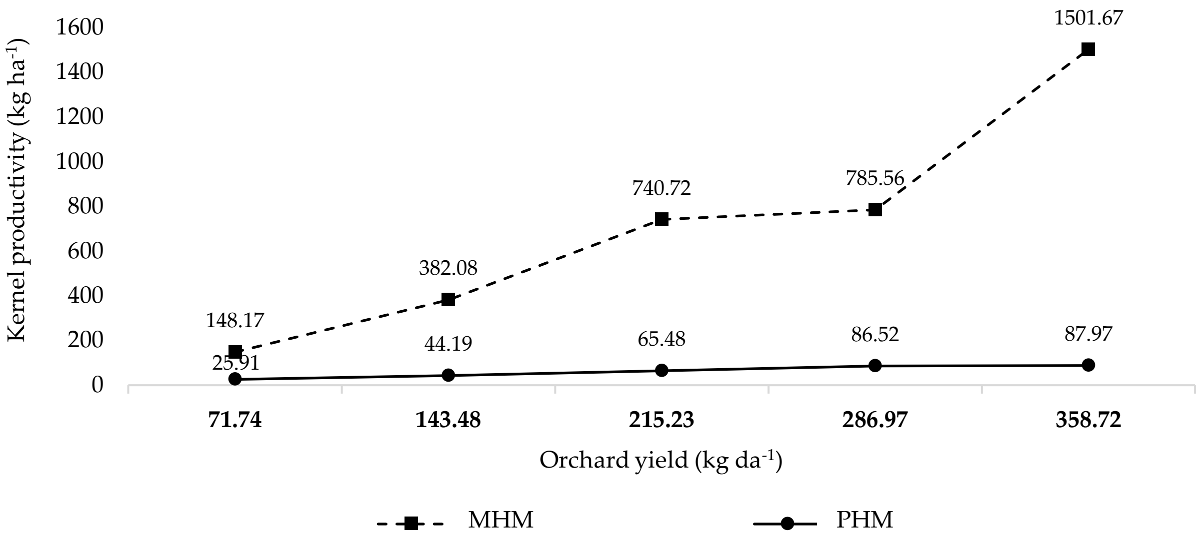

Figure 3. Kernel productivity values obtained under different orchard yield conditions.
Şekil 3. *Farklı bahçe verimi koşullarında elde edilen ürün iş başarısı değerleri.*

As seen in Figure 3, in the kernel productivity values of the machines milling dried hazelnuts, there is an increase due to the increase in orchard yield. In the study with PHM, this increase in kernel productivity is lower and at the same level for all orchard yields. In the study with MHM, it increases rapidly after 286.97 kg da^{-1} orchard yield. Again, as seen in Figure 3, depending on the orchard yield, It can be said that if hazelnuts are harvested with MHM instead of PHM, the increase in kernel productivity is significant.

CONCLUSION

In the experiments carried out to investigate the possibilities of mechanical harvesting of hazelnuts grown in flat and nearly flat lands in Turkey, harvesting efficiency, field productivity, and kernel productivity characteristics of the machines were determined.

Accordingly, there was an increase in the harvesting efficiency values of MHM and PHM due to the increase in orchard yield. The harvesting efficiency values ranged between 92.54...96.03% and 97.68...99.36%, respectively. Beyhan (1992) designed and manufactured an aspiration hazelnut harvesting machine suitable for Turkish conditions, In the case of orchard yields of 113.4, 226.8, and 340.2 kg da^{-1}, the harvesting efficiency of the machine was 92.43%, 95.13%, and 95.73%, respectively. Yıldız (2000), in his research on the design of a prototype hazelnut harvesting machine with a tractor-operated mechanical ground harvesting unit, 225 kg da^{-1} orchard yield and 3.2 km h^{-1} machine working velocity, the harvesting efficiency was reported to be 91.66%. Ghiotti (1989), in a study carried out under Italian conditions with a machine with chain link harvesting arrangement, the harvesting efficiency of the machine was found to vary between 86-89%. Keskin (2004), reported that in a rubber finger-type harvesting unit that can harvest hazelnuts from the ground, the harvesting efficiency was 90.17% under 100 kg da^{-1} orchard yield conditions. While no significant difference was observed between the harvesting efficiency values of both machines, it is also consistent with the literature reports given above.

In the study with MHM and PHM, depending on the increase in orchard yields, while there is an increase in machine labor and machine+human labor requirements, there is a decrease in field productivity and machine+human field productivity values. For MHM and PHM, the change in the values of labor requirement, machine+human labor requirement, field productivity obtained by using only machine and field productivity obtained by using machine+human labor are as follows; for MHM; 6. 349-9.839 MİGh ha^{-1}, 46.228-62.531 BİİGh ha^{-1}, 0.158-0.102 ha $MİGh^{-1}$, 0.022-0.016 ha $BİİGh^{-1}$, for PHM; 70.394-105. 647 MİGh ha^{-1}, 108.509-147.481 BİİGh ha^{-1}, 0.014-0.009 ha $MİGh^{-1}$, 0.009-0.007 ha $BİİGh^{-1}$. Beyhan (1992), in his study on the design and manufacturing of an aspiration hazelnut harvester suitable for Turkish conditions, reported that the field productivity values of the machine were 0.428, 0.396, and 0.352 da h^{-1} for orchard yields of 113.4, 226.8 and 340.2 kg ha^{-1}, respectively. Yıldız (2000), in his research on the design of a prototype hazelnut harvesting machine with a tractor-operated mechanical ground harvesting unit, reported that the field productivity values of the machine varied between 1.50-1.10 da h^{-1} when the orchard yields were 75, 150 and 225 kg da^{-1}. Yıldız and Tekgüler (2012), in their study comparing the labor requirement and work success of a hand-held, shoulder-hung eccentric type shredder with the traditional (handshaking and hand harvesting) method; the main time was 97.73 h ha^{-1} with handshaking and 114.12 h ha^{-1} with shredder; the auxiliary time was 0.48 h ha^{-1} with handshaking and 35. 82 h ha^{-1}; unavoidable time 0.98 h ha^{-1} with manual shaking, 6.91 h ha^{-1} with shredder; effective working times 99.19 BİİGh ha^{-1} with manual shaking, 156. 86 MİGh ha^{-1}; field productivity was 0.0101 ha $BİİGh^{-1}$ with handshaking and 0.0064 ha $MİGh^{-1}$ with shredder; field productivity was 1.01 da day^{-1} (10 h) with handshaking and 0.64 da day^{-1} (10 h) with the shredder. Although the harvesting efficiency of PHM is high, their field productivity is quite low. As the orchard yield increases, labor requirements increase, and field productivity decreases. This situation is because with the increase in orchard yield, the hazelnuts that cannot be harvested by the machine are harvested by hand and the time for bag tying-unloading increases. In the harvesting of hazelnuts with PHM, with the increase in orchard yield, the operator's rest and refueling time increases, which decreases the field productivity of the machine. However, due to the high yield of the orchard and the consequent density of hazelnuts on the ground, the delivery hose was moved slowly and sometimes passed through the same area more than once. As the orchard yield decreased, this situation was relatively eliminated. The results obtained from the harvesting trials with the MHM show a labor-saving of approximately 96.95% compared to traditional manual harvesting and 90.68% compared to PHM harvesting.

MHM and PHM showed an increase in kernel productivity values due to the increase in orchard yield. The change in the kernel productivity values of MHM and PHM varied between 124.83-1322.08 kg ha^{-1} and 18.90-67.18 kg ha^{-1}, respectively. Ghiotti (1989) conducted a study with a drum (metal chain) self-propelled hazelnut harvesting machine, If the orchard yield is 122.6 kg da^{-1}, the kernel productivity of the machine is 177 kg ha^{-1}, and if the orchard yield is 173 kg ha^{-1}, the kernel productivity of the machine is 207 kg ha^{-1}. Beyhan (1992) designed and manufactured an aspiration hazelnut harvesting machine suitable for Turkish conditions, In the case of orchard yields of 113.4, 226.8, and 340.2 kg da^{-1}, the kernel productivity of the machine was 44.86, 85.44, and 114.63 kg ha^{-1}, respectively. Yıldız (2000), in his research on the design of a prototype hazelnut harvesting machine with a tractor-operated mechanical ground harvesting unit, determined that the kernel productivity of the machine was 100.29 kg ha^{-1} (as milling dry kernel) when the orchard yield was 225 kg ha^{-1}. Fanigliulo and Tomasone (2009), in their study in which they determined the operating characteristics of a self-propelled mechanically effective hazelnut harvester, reported that the kernel productivity of the machine was 2.5 t h^{-1}. Pagano et al. (2011), in their study to determine the performance values of a hazelnut harvesting machine with a mechanical harvesting unit (at a working velocity of 1.5 km h^{-1}), determined that the product success of the machine was 1.25 t h^{-1}. A significant difference is observed between the kernel productivity values of both machines. It can be said that this difference is because MHM is a self-propelled machine and the working width is higher.

As a result, when the MHM developed as a prototype is mass-produced, it will be able to provide economic and agronomic benefits for hazelnut producers, such as reducing the harvesting cost and demand for labor, and on the other hand, preventing damage to the trees as a result of hazelnut harvesting. Thus, an important step will be taken for the mechanization of hazelnuts, which is one of the most important problems in our country, with the production of a machine suitable for our orchard structure and hazelnut varieties.

ABBREVIATIONS

MİGh ha^{-1}	machine labor hour / hectare
BİİGh ha^{-1}	unit human labor hour / hectare
ha MİGh^{-1}	hectare / machine labor hour
ha BİİGh^{-1}	hectare / unit human labor hour

CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest related to this article.

DECLARATION OF AUTHOR CONTRIBUTION

The authors contributed equally to each stage of the study.

ACKNOWLEDGMENT

This study was compiled from his doctoral thesis and supported by OMU ZRT.1904.11.021 numbered project by BAP. We would like to thank Ondokuz Mayıs University Project Management Office

REFERENCES

Beyhan, M. A. (1992). Ülkemiz koşullarına uygun aspiratörlü bir fındık hasat makinasının tasarım ve imalatı. [Doktora Tezi, Ankara Üniversitesi]. https://tez.yok.gov.tr/UlusalTezMerkezi/

Beyhan, M. A., & Yıldız, T. (1996, Ocak 10-11). Fındık ve diğer sert kabuklu meyvelerde uygulanan mekanik hasat yöntemleri. Fındık ve Diğer Sert Kabuklu Meyveler Sempozyumu, Samsun.

Beyhan, M. A., & Sauk, H. (2018). Türkiye'de fındık tarımında mekanizasyon durumu. *TÜRKTOB Dergisi*, *27*, 22-27.

Biondi, P., Monarca, D., & Zoppello, G. (1992). La Meccanizzaione Della Coltura del Nocciolo. Estratto da Macchine & Motori Agricoli-il Trattorista, 50(4), 29-48.

Caran, D. (1994). Zeytinde mekanik hasat olanaklarının araştırılması. [Doktora Tezi, Ege Üniversitesi], https://tez.yok.gov.tr/UlusalTezMerkezi/

Fanigliulo, R., & Tomasone, R. (2009, October 31). Operative performance and work quality of a hazelnut pick-up machine. ISHS Acta Horticulture 845: VII International Congress on Hazelnut. https://doi.org/10.17660/ActaHortic.2009.845.66

Ghiotti, G. (1989). Self-propelled machine for harvesting hazelnuts. Journal of Agricultural Engineeing. 20(3), 174-183.

İlkyaz, H. (1986). Doğu Karadeniz Bölgesi'nde çay ve fındığın üretim girdi ve maliyetleri. Tarım Orman ve Köyişleri Bakanlığı, Köy Hizmetleri Araştırma Enstitüsü Müdürlüğü Yayınları, Genel Yayın, (38).

Keskin, L. (2004). Fındık hasat makinası için mekanik bir toplama ünitesinde bazı yapısal ve işletme parametrelerinin fonksiyonel özelliklerine etkisi. [Yüksek Lisans Tezi, OMÜ], https://tez.yok.gov.tr/UlusalTezMerkezi/

Monarca, D., Cecchini, M., & Antonelli, D. (2005, July 30). Innovations in harvesting machines. ISHS Acta Horticulturae 686: VI International Congress on Hazelnut. https://doi.org/10.17660/ActaHortic.2005.686.48

Monarca, D., Biondi, P., Cecchini, M., Santi, M., Guerrieri, M., & Colantoni, A. (2008, September 15-17). Evaluation of respirable dust exposure during hazelnut and chestnut mechanized harvesting. International Conference. Ragusa/Italy.

Pagano, M., Fanigliulo, R., Tomasone, R., Cedrola, C., Recchi, P. F., & Colorio, G. (2011, December 31). Mechanical hazelnut harvesting: First results of a pick-up prototype for a low environmental impact. ISHS Acta Horticulture 919: XXVIII International Horticulture Congress on Science and Horticulture for People (IHC2010). https://doi.org/10.17660/ActaHortic.2011.919.17

Tous, J., Girona, J., & Tasias, J. (1994, September 14-18). Cultural Practices and Costs in Hazelnut Production. III. International Congress on Hazelnut, Alba, Italy, Acta Horticulture, 351, p. 395-418. https://doi.org/10.17660/ActaHortic.1994.351.44

TÜİK. (2023). Bitkisel üretim istatistikleri. https://data.tuik.gov.tr/Kategori. [Erişim tarihi: 12 Aralık 2023].

Yıldız, T. (2000). Traktörle çalıştırılabilir mekanik-yerden toplama üniteli bir fındık hasat makinasının tasarımı, [Doktora Tezi, Ankara Üniversitesi], https://tez.yok.gov.tr/UlusalTezMerkezi/

Yıldız, T., & Tekgüler, A. (2012, Eylül 5-7). Eksantrik tipli silkeleyiciyle hasadında iş başarılarının belirlenmesi. 27. Tarımsal Mekanizasyon Ulusal Kongresi, cilt.1, ss.332-339, Samsun.

Yıldız, T. (2016). Labor requirements and work efficiencies of hazelnut harvesting using traditional and mechanical pick-up methods. *Turkish Journal of Agriculture and Forestry*, 40(3). https://doi.org/10.3906/tar-1508-114

Zoppello, G., & Tempia, D.P. (1988). Considerazoni su una Nuova Macchina Per la Raccolta delle Nocciole. L'Infarmatore Agrario, XLIV (9), Verona, 105-114.