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DETERMINATION OF ERGONOMIC FACTORS OF THE BACKPACK BLOWERS USED IN THE WINDROW OF HAZELNUTS

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Abstract: Ergonomics plays an important role in the design and use of agricultural machinery to protect the health and safety of workers. Lack of ergonomic design negatively affects worker discomfort and safety. Therefore, ergonomic design should ensure that workers can work comfortably, maintain correct posture, and minimize the risk of injury. Especially workers using backpack machines are exposed to physical fatigue, posture problems, risk of injury, and ergonomic effects due to vibration and noise. Considering all these, this study was conducted to determine the ergonomic factors (ergonomic analysis of the operator's working posture, operator's fatigue values, noise level, and dust concentration) that the operator is exposed to as a result of different body positions and moving the air diverter hose while using the backpack type blowers used to windrow the kernel+husked nuts falling on the orchard ground during the hazelnut harvest period. According to this, in all three ergonomic risk methods, the operator's body posture was found to be risky, and ergonomic adjustments were needed. Again, the operator's fatigue value, noise level, and dust concentration were obtained as 10.43 kcal min^{-1}, 91.70 dB(A)-106.20 dB(A) (average 98.95 dB(A)), 19.241-21.390 mg m^{-3}-air (average 20.315 mg m^{-3}-air), respectively. The identification of ergonomic factors is also very important to improve the user experience, prevent occupational accidents, and improve machine performance in general. With the identification of these factors, optimized solutions for the safety and comfort of users will be put forward by adopting a human-centered approach in machine design.

Keywords: Ergonomic, Backpack blower, Hazelnut harvester

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1. Introduction

The main purpose of ergonomics is to design and organize work or living environments where people and technology come together so that users can work effectively, efficiently, and safely. Working conditions need to be improved and harmonized with the employee. Accordingly, it will be possible to increase the performance of the employee by ensuring the health, safety, and comfort of the employee. Since agricultural activities have a dynamic structure, it is more difficult to systematically analyze the ergonomic factors to which employees in the agricultural sector are exposed compared to other sectors (Mert, 2014; Kır, 2015; Sauk et al., 2022).

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. Although the use of human labor requirement has decreased somewhat with the development of mechanization, the use of the labor force continues during hazelnut harvesting (Beyhan and Sauk, 2018). Three different harvesting methods are generally applied in the mechanical harvesting of hazelnuts. The first of these is the harvesting of the hazelnut kernel+husked nuts into windrow with the help of a backpack-type blower after orchard cleaning by aspiration harvesting machines. The second one is orchard cleaning followed by harvesting with aspiration harvesting machines and finally harvesting the hazelnuts with mechanical sweepers by sweeping the hazelnuts into a windrow and harvesting the hazelnuts with machines with mechanical harvesting units. With these methods, hazelnut harvesting is completed in a short time and costs can be reduced significantly (Biondi et al., 1992; Beyhan and Yıldız, 1996; Tous, 2001; Monarca et al. 2005; Fanigliulo and Tomasone, 2008).

Backpack-type leaf blowers are generally used for orchard maintenance and cleaning works. However, in recent years, in our country, it has been used both to obtain a clean orchard ground before harvesting by cleaning the foreign material residues on the ground before the hazelnuts fall on the orchard ground and to windrow the hazelnuts on the orchard ground during the harvest period. By windrow the hazelnut, the harvesting process is shortened and the working efficiency is increased. Thus, a fast and effective hazelnut harvest helps to save time and labor, reduce soil contamination, and obtain a cleaner and healthier product (Beyhan, 1992; Bernardi et al., 2017), However, in addition to all these advantages, carrying these machines on the back may cause ergonomic problems in long-term use. As the weight of the loads carried on the back increases, there is an increasing forward bending and strain on the knees, and similarly, as the load begins to descend from the shoulder to the waist, the forward bending of the trunk increases. The World Labor Organization (ILO) and individual countries have "Maximum Transportable Load" decisions and practices for this type of back-carrying work (Anonymous, 2016). It has been reported that the use of back-carrying type machines increases the body load of employees, will cause musculoskeletal disorders (MSSR) in long-term work, the vibration created by the machine spreads along the entire back, hands, and arms, which develops physiological and biomechanical stress, and also causes pain in the palm and wrist areas of the hand grip (Kumar et al., 2011; Halim et al., 2019; Ajid, 2021; Aygün et al., 2021).

Ergonomics plays an important role in the design and use of agricultural machinery to protect employee health and safety. Employees using this type of machinery are exposed to physical fatigue, posture problems, risk of injury, and ergonomic effects due to vibration and noise. In addition, the lack of ergonomic design also negatively affects the discomfort and safety of the worker. Therefore, ergonomic design should ensure that workers can work comfortably, maintain correct posture, and minimize the risk of injury. Considering all these, backpack blowers have started to be widely used by farmers in the region in recent years to windrow the hazelnuts that fall on the orchard ground during the hazelnut harvest period. These factors aim to provide an optimized solution for the safety and comfort of users by adopting a human-centered approach to machine design. These factors aim to provide an optimized solution for the safety and comfort of users by adopting a human-centered approach to machine design.

2. Materials and Methods

2.1. Materials

The study was conducted in a farmer's orchard located in Çarşamba district of Samsun province (41°17'59"N 36°43'15"E). The hazelnut orchard where the trials were conducted has Palaz and Çakıldak hazelnut varieties which are widely grown in the region. During the trials, the air temperature was 29.20 °C, relative humidity was 58.21% and wind speed was 0.50-0.65 m s^{-1}.

The backpack blower used in the study consists of six main units: engine, blowing unit, air routing system (blowing hose), control and control unit, carrying system (such as handle and shoulder straps), and fuel tank. Technical specifications of the machine are given in Table 1. These units are the basic components of backpack blowers. However, depending on the model and mark, the design and features of these units may vary.

Noise measurements of the machine were made with a handheld device model TES 1351B, IEC61672-1 Class 2, with a measurement range of 35-130 dB(A) and a sensitivity of 0.1 dB. Before each measurement, the noise meter was calibrated with a CEM SC-05 model 23 calibrator with a signal of 94 dB(A) at 1000 Hz. Operator fatigue values were determined using a Geonaute model On the Rhythm 410 program clock and chest strap. Dust concentration was measured using an AeroTrak APC 9303-01 handheld particle meter with a particle size range of 0.3, 2.5, and 5 µm.

Table 1. Technical specifications of the backpack blower used in the trials

Mark	Stihl BR 700
Cylinder volume (cc)	64.80
Power (kW)	2.80
Weight (kg)	10.80
Air flow rate (m^3 h^{-1})	1550
Blowing speed (m s^{-1})	74
Blowing power (N)	35

2.2. Method

To determine the ergonomic factors of the backpack-type blower, experimental plots were formed in the orchard with an average of 4.90 m between rows and 4.85 m above rows, each plot containing 10 hazelnut brushes ("ocak" in Turkish). The experiments were carried out with three replications according to the randomized plots experimental design under the condition of 189 kg da^{-1} average orchard yield as milling dry hazelnut with 10% moisture content (y.b.). In each plot, the hazelnuts with kernel+husked nuts in the ocak, between the rows and above the rows were blown between the rows to form a windrow. During the studies, a 46-year-old male operator, 172 cm tall and 94 kg in weight, was used. Images from the hazelnut orchard where the experiments were carried out and during the operation of the operator are given in Figure 1.

2.2.1. Determination of operator's ergonomic risk analysis

The tasks performed by the operator during the windrow of hazelnuts were examined, and work postures were documented. No intervention was made to the operator during the experiments. The body postures of the operator during work were determined using the ergonomic risk assessment methods of REBA, OWAS, and RULA, and risk scores and action plans were identified. In the work environment, various methods are used to determine the ergonomic risk levels based on the nature of the tasks. For tasks predominantly involving the upper body (hand, wrist, elbow, upper arm, shoulder, and neck) performed repetitively in agricultural activities, RULA (Rapid Upper Limb Assessment) is commonly used. Tasks are grouped, and based on the percentage of total working time that each posture covers, OWAS (Ovako Working Posture Analyzing System) is preferred. For the evaluation of dynamic and static body postures, the REBA (Rapid Entire Body Assessment) method is widely used.

Figure 1. General view of the hazelnut orchard during the trials.

As a result of the analysis, the physical load scores of the workers were determined, and an ergonomic risk assessment was conducted (Eminoğlu and Koç, 2018; Sauk et al., 2022). ErgoFellow 2.0 software package was used for the examination of images.

2.2.2. Determination of operator fatigue values

During the experiments, the operator's heart rate values were measured using telemetry (remote measurement) (Eminoğlu et al., 2012). In this method, the transmitter part of the device was attached to the operator's chest throughout both work and rest periods. The heart rate, maximum heart rate (BPM), total energy consumption (kcal), and the amount of burned fat (g) were recorded. The chest strap is attached to the operator's body as seen in Figure 2.

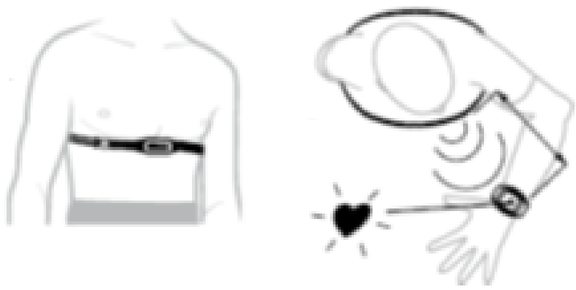

Figure 2. Attachment method of the chest band.

The total energy consumed by the operator in each plot was measured, and the energy consumption per minute was obtained by dividing the total time spent during the windrow of the kernel+husked nuts in the plot with a backpack blower. Before the start of the trials, the operator's heart rate was measured with the help of a chest strap, and after each plot was blown and windrow, the trials were interrupted until the operator's heart rate reached the initial heart rate. The energy consumption of the operator was compared with the recommended limit value of 10 kcal min^{-1} for seasonal workers. Using the energy consumption, the rest intervals of the operator were determined with the help of the following Equation 1 (Sabancı et al., 2012).

$$RTR = [(EC - 4\ kcal)\ /\ EC].100 \quad (1)$$

where; RTR= Rest time rate (%) and EC= Energy consumption (kcal min^{-1}).

2.2.3. Determination of the noise level

The noise level of the machine was measured for five minutes with the microphone of the measuring device at the operator's ear level. The noise level was measured in dB(A) and the instrument was calibrated before each measurement. The noise level exposed during the operation of the machine was taken as the warning limit of 85 dB(A) and the hazard limit of 90 dB(A), which are recommended for the health of people under the influence of different levels of noise according to the noise control regulation and compared with these values (Sauk, 2016).

2.2.4. Determination of dust concentration

To determine the dust concentration values of the backpack-type blower, measurements were made for 30 minutes with the dust measuring device at a height of 1.5 m above the ground. The measurement points were determined by the purpose of the study, within the working area of the operator. The average of the dust concentration values obtained are given. As a result of the measurements; $PM_{0.3}$ (0.3 µm), $PM_{2.5}$ (2.5 µm), and $PM_{5.0}$ (5 µm) dust concentrations were determined in µg m^{-3}-air. The dust levels generated in the environment during the operation of the machine were compared considering the dust concentration threshold limit of 3 µg m^{-3}-air value specified in occupational health and safety legislation and regulations (Sauk, 2016).

3. Results and Discussion

3.1. Ergonomic Risk Analysis of the Operator

Risk scores and action plans of the operator's body postures during work using REBA, OWAS, and RULA ergonomic risk methods are given in Table 2.

Table 2. Operator's risk scores and action plan according to ergonomic risk analysis methods

Ergonomic risk method	Obtained risk score	Action plan
REBA	7	Medium risk, precautions required
OWAS	Category 3	Working postures have clear detrimental effects on the musculoskeletal system. Ergonomic adjustment for these postures is needed as early as possible.
RULA	6	Medium risk, change required soon

As can be seen from Table 2, in all three ergonomic risk methods, the operator's body posture was found to be risky, and ergonomic adjustments were needed. Carrying the blower on the back increases the physical load of the operator. Considering the REBA, OWAS, and RULA scores obtained in the back carrying, it is predicted that it may lead to MSSR in long-term working conditions. The observations and results from the measurements show that the windrow of hazelnuts with the backpack blower takes place under non-ergonomic conditions. The weight of the blower forces the operator to keep himself in a position of balance. In this case, the load not only increases the strain on the knees over time but also increases the forward tilt of the trunk when the load starts to descend from the shoulder to the waist. Carrying the machines on the back for a long time is the most difficult situation for the operator. To minimize this kind of physical strain, the operator should take a break from working at certain intervals.

3.2. Operator Fatigue Values

Before the start of the study, the operator's heart rate per minute was 78 BPM, maximum heart rate was 82 BPM, energy consumption was 2.2 kcal min^{-1} and the amount of fat burned was 0.21 g. The number of heartbeats, total energy consumption, amount of fat burned, weight of hazelnuts (kernel+husked nuts), and windrow times measured in the experimental plots where fatigue tests were performed are given in Table 3.

Table 3. Parameters of operator fatigue values measured in trial plots

Parameters	Average values
Weight of hazelnuts in the plot (kg)	44.92
Windrow making time (sec)	725
Heart rate (BPM)	118
Total energy consumption (kcal)	126
Amount of fat burned (g)	6.20

As seen in Table 3, during the windrow of 44.92 kg of hazelnuts in the experimental plot with a backpack blower, the operator's heart rate, total energy consumption, amount of fat burned, and windrow time were 118 BPM, 126 kcal, 6.20 g and 725 seconds, respectively. During the windrow of the hazelnuts in the plot, the energy expended by the operator per minute was 10.43 kcal min^{-1}. Again, the energy value that the operator will need to windrow 1 kg of hazelnuts is 2.80 kcal kg^{-1}-nut. According to the energy consumption of the operator in 725 seconds, the resting time ratio is approximately 61.64%. In other words, in 1 hour period, the operator must devote approximately 36.98 minutes to resting.

3.3. Operator’s Exposed Noise Level

The minimum, maximum, and average noise level values of the backpack blower were 91.70 dB(A), 106.20 dB(A), and 98.95 dB(A), respectively. Since sounds with noise levels above 85 dB(A) have effects such as temporary and permanent hearing loss, the International Labor Organization (ILO) has accepted 85 dB(A) as the warning limit and 90 dB(A) as the dangerous limit (Sabancı et al., 2012). Accordingly, it is not suitable for the operator to work with this machine continuously for 8 hours a day. The operator can work for a maximum of 3-4 hours continuously.

3.4. Operator’s Exposed Dust Concentration

The lowest and highest measurement range of dust concentrations in the environment during the windrow of hazelnuts with a backpack blower according to $PM_{0.3}$, $PM_{2.5}$, and $PM_{5.0}$ diameter groups are given in Table 4. Dust concentration values were converted to mg m^{-3}-air.

Table 4. Variation of the dust concentrations created by the machines in the environment according to the lowest and highest measurement range according to diameter groups

Particle Diameter (µm)	Dust concentration (mg m^{-3}-air)	
	Lowest	Highest
$PM_{0.3}$	7.501	8.218
$PM_{2.5}$	6.927	7.448
$PM_{5.0}$	4.813	5.724
PM_{10}	19.241	21.390

As seen in Table 4, the lowest and highest values of the dust concentrations emitted by the machine to the environment according to $PM_{0.3}$, $PM_{2.5,}$ and $PM_{5.0}$ µm diameter groups were measured between 7.501-8.218 mg m^{-3}-air, 6.927-7.448 mg m^{-3}-air, and 4.813-5.724 mg m^{-3}-air, respectively. Total (PM_{10}; particle diameter less than 10 µm) dust concentration values emitted by the machine ranged between 19.241-21.390 mg m^{-3}-air (average 20.315 mg m^{-3}-air). These values are above the threshold limit of 3 mg m^{-3}-air for respirable dust in the ACGIH TLV standard. As a result, dust concentrations are above the threshold limit value and are at a level to adversely affect the health of workers.

4. Conclusion

Ergonomic analysis of the working postures, fatigue values, noise level, and dust concentration values of the backpack-type blowers used to windrow the hazelnuts that fall on the orchard ground during the hazelnut harvest period was determined as a result of different body positions and moving the air diverter hose while using the blowers in the orchard on the operator's back.

Accordingly, the use of the backpack blower had the highest ergonomic risk scores affecting worker health. Among the ergonomic risk factors, improper body posture, repetitive movements, and ergonomic inadequacy of the tools used are important factors that cause MSSR. Considering that these factors are the movements that are frequently performed during the windrow of hazelnuts, it can be said that the backpack blower causes MSSR. From this point of view, if the existing machines are to be used, it is necessary to have a sufficient number of employees so that employees can be rotated among them. However, it can be said that this will bring an additional burden to the harvesting cost.

According to the energy expended by the operator to windrow the hazelnuts with the backpack blower, working with this machine is classified as heavy work. The use of a backpack blower can cause different fatigue levels in people depending on many factors. The operator should take regular breaks, exercise regularly, eat a balanced and healthy diet, have good sleeping habits, and avoid stress. In addition, the weight of the machine and its handling systems will affect the user's comfort in handling and using it, so they should prefer machines with a lightweight and ergonomic design. Implementing these measures can help prevent fatigue in the work environment.

The noise level may vary depending on the type of engine used, power level, make, and model specifications. Gasoline-powered models generally have a higher noise level, so the operator may need to wear hearing protection such as business headsets or earplugs. It is preferable to use equipment with low noise levels (such as models powered by electric motors). Training and raising awareness among workers on noise handling and protection is also important.

The high dust concentration created by the backpack-type blower in the environment is due to the working principle of the machine. During the circulation of the air guide hose of the machine on the orchard ground, particles such as leaves, small branches, small stones, soil, and coarse dust together with hazelnuts with kernel+husked nuts are mixed into the air during blowing from the orchard ground and dust is formed. Working in such an environment may involve potential risks of damage to the respiratory tract and skin. When working with this type of machine, the operator should wear dust masks or respiratory protection masks, goggles to prevent dust contact with the eyes, and appropriate clothing (such as long sleeves and leggings) to protect the skin.

In conclusion, with the increasing level of mechanization, the necessity of investigating the hazards and risks of new systems in terms of occupational health and safety and preventing the identified risks through continuous improvement has become evident. In such researches, examining the working conditions from an ergonomic point of view, putting forward and implementing improvement suggestions will play an important role in reducing occupational accidents as well as protecting employee health.

Author Contributions

The percentage of the author(s) contributions is presented below. All authors reviewed and approved the final version of the manuscript.

	H.S.	K.M.U.
C	55	45
D	100	
S	100	
DCP	70	30
DAI	100	
L	60	40
W	60	40
CR	60	40
SR	60	40
PM	60	40
FA	60	40

C=Concept, D= design, S= supervision, DCP= data collection and/or processing, DAI= data analysis and/or interpretation, L= literature search, W= writing, CR= critical review, SR= submission and revision, PM= project management, FA= funding acquisition.

Conflict of Interest

The authors declared that there is no conflict of interest.

Ethical Consideration

Ethics committee approval was not required for this study because of there was no study on animals or humans.

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