XVII[th] World Congress of the International Commission of Agricultural and Biosystems Engineering (CIGR)

Hosted by the Canadian Society for Bioengineering (CSBE/SCGAB)
Québec City, Canada June 13-17, 2010

COMPARISON OF TRACTOR-ROTARY TILLER COMBINATION AND POWER TILLER IN TERMS OF ENERGY EXPENDITURE OF OPERATORS

BARIŞ EMINOGLU[1], ABDULLAH BEYAZ
OKRAY OREL, GALIP OZTURK, RAMAZAN OZTURK, ALI IHSAN ACAR

[1]Ankara University, Agriculture Faculty, Department of Agricultural Machinery, 06130 Aydınlıkevler TURKEY, eminoglu@agri.ankara.edu.tr

CSBE101007 – Presented at Section V: Management, Ergonomics and Systems Engineering Conference

ABSTRACT Many different equipment and machinery have been used while performing agricultural operations. Some equipment and machines can be used to perform the same operation. When a user is purchasing equipment he often considers the power output, maintenance capability and ease of use before choosing a specific machine. In this study, we compared an operator's energy consumption for working a rotary tiller mounted tractor with a power tiller that has the same working width. Energy consumption of operators was measured by SensWear Armband when performing hoeing a field operation. Measurements were taken for the operation of four different machines at three different forward speeds. Three experienced operators participated in this research experience. Measurements of energy consumption values were statistically analyzed using Minitab 15.0 and MSTAT. Variance analysis showed that forward speed, operator, type of machine showed interactions that were statistically significant ($p<0.01$). Based on the findings of these analysis; energy consumption of operators increased with the increasing of forward speed. Energy consumption value of each operator was different when working with power tiller. Energy consumption value of tilling operation with power tiller was higher than that of the rotary tiller mounted tractor.

Keywords: Tractor, rotary tiller, Power tiller, hoeing, energy expenditure, human performance

INTRODUCTION One of the aims of ergonomics is to reach somebody's maximum performance with less strain and also to provide high level of work safety. Human energy expenditure for work is an important factor to determine a permanent physiological impact will occur or not. Also it is important for assessment of work efficiency (Babalık, 2005).

Many investigations were accomplished about human performance and strain until today. Kang et al. (2007) investigated relationship between workload and maximal physical work capacity (MPWC) and distribution of MPWC. Subjects were 507 male workers from several metal industries in Korea. They found a negative relationship between MPWC and workload across all age groups. Müller and Coetsee (2008) made a research to determine differences in energy expenditure and working efficiency of sugarcane

cutters with regard to harvesting burnt and unburnt sugarcane. The experiment was made by 15 male subjects. As a result of this work, they indicated that energy requirement for harvesting per kilogram unburnt sugar cane is 2.13 kJ and for harvesting per kilogram burnt sugar cane is 1,51 kJ. Also they found that harvesting burnt cane required significantly more cutting strokes per minute than unburnt cane.

Agricultural occupations require much physical efforts and are widely affected from environmental conditions. Timeliness is an important factor regarding a successful outcome in agricultural work. Therefore, using of farm machinery is indispensable. Different types of equipment and machinery can be used to perform the same work in agricultural operations. Users take into consideration their economic purchasing power, maintenance capability of machine or equipment and recently they look for ease of use. For this reason, agricultural equipments and machines must be practical.

In Turkey, approximately 54.7% of all agricultural enterprises have 0-49da area. The average cultivated area of these enterprises is 20da (TUIK, 2006). These enterprises are suitable for orchards, vineyards and growing vegetables. Power tillers and tractor-rotary tiller combination can be used to cultivate orchards and vineyards.

Power tillers are usually used for land preparation in dry and wet land conditions. They are particularly suitable for small size fields. A power tiller operator walks behind the machine during the working period. Also the operator has to control forward movement and guide the machine while turning at headlands. Additional environmental conditions make the work harder. All of these factors cause fatigue on the operators (Tiwari and Gite, 2006).

Tractors which have been used for orchard and vineyard are low type. Also they have constructed like having a narrow-track width. In recent years, orchard and vineyard tractors have become widespread in Turkey (Silleli, 2007).

In this study, operators' energy expenditure values were compared for working with tractor-rotary tiller combination and power tiller. Findings of the research were assessed and than some suggestion were recommended for users.

MATERIAL

Machines For this research, hoeing operation was performed in a field with power tiller and tractor rotary tiller combination. A power tiller which has an 8hp diesel engine was used. Its working width is 90cm. Its weight is about 120kg. Experiments were made at second forward speed.

The tractor which was used for the research has a 16hp diesel engine. A rotary-tiller mounted the tractor. Its working width is also 90cm. Tractor- rotary tiller combination was operated at second low forward speed.

Subjects Three well-acquainted male workers were selected randomly. They have enough field experience of operation with power tiller and tractor-rotary tiller combination. Physiological characteristics of selected workers were given in Table 1.

Table 1. Physiological characteristics of the subjects

Operator No	Age (years)	Height (cm)	Weight (kg)
1	27	175	70
2	23	190	91
3	26	175	77

They had no physical ailment. Before every experiment the subjects were asked to indicate any pain or discomfort.

METHOD

Experiment procedure This study was carried out in orchards which belong to Ankara University Faculty of Agriculture. The soil surface condition was dry and undulating. The weather during the experiment period was clear with the mean temperature and relative humidity varying between 15.0–22.0^{o}C and 22.3–47.7%, respectively.

In this research, operating depth was adjusted at 10 cm for operation with both machines. The trials were conducted at selected three forward speed levels; 1.6 km/h, 2.1 km/h, 2.6 km/h. To get these forward speeds, both machines were run through 100metres in field and headway time was determined. Forward speeds were adjusted with hand throttle lever at tractor and gas clutch at power tiller.

The experiment was conducted at different time intervals of the day between 9:00 AM and 5:30 PM. The trials were given in random order to minimize the effects of variation in environmental and soil factors. Each subjects had two rests for 10 minutes before starting trial and after hoeing operation. The subjects operated the machines for an hour. Each subject worked at there different forward speed with two machines and every trial pattern was repeated there times.

Determining energy expenditure Energy consumption of workers is determined by indirect calorimetry methods in real working conditions. The most common of these methods are measuring oxygen consumption value and heart rate of the subjects. Then these values are used in various equations.

Malavolti et al. (2007) assessed resting energy expenditure values of ninety nine subjects using a Sensor Medics Vmax metabolic cart with a ventilated canopy and with SenseWear armband. They found no significant difference in resting energy expenditure (REE) between SenseWear and Sensor Medics Vmax. They remarked that correlation between REE measured by SenseWear and Sensor Medics Vmax was high ($r=0.86$, $p<0.0001$)

In this study, because of ease of using at field research and transferring data from device to computer, a portable armband was used. (Figure1.)

Figure 1. Armband used to measuring energy expenditure values.

Energy expenditure values of subjects were measured SenseWear armband. The armband was placed on the upper right arm over the triceps muscles of each subject. It uses a 2-axis accelerometer, a heat flux sensor, a galvanic skin response sensor, a skin temperature sensor, and a near-body ambient temperature sensor to capture data. These data as well as body weight, height, handedness, and smoking status (smoker or non smoker) are used to calculate energy expenditure values with SenseWear Professional 6.1 program which was provided by manufacturer.

We used the active energy expenditure values and physical activity duration to calculate energy consumption of subjects in a minute (kcal/min). Interface of program which including type of using data was given in Figure2.

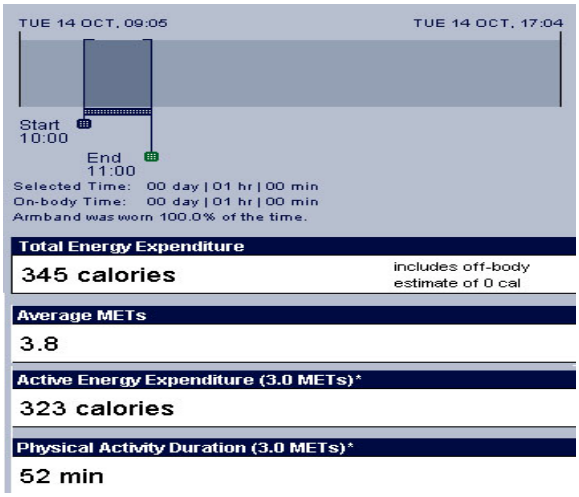

Figure 2. Interface of SenseWear Professional 6.1

Data analysis Retrieved observations in terms of energy consumption were evaluated by the Three-way ANOVA. There are three levels of operator factor which no1, no2, no3; two levels of machine factor are power tiller and tractor-rotary tiller combination; three levels of forward speed are 1.6km/h, 2.1km/h and 2.6km/h.

As a result of conducted analysis of variance if necessary DUNCAN multiple comparative tests were used to determine different means. Results were indicated next to the required mean with form of letter representation.

Minitab 15.1 statistical package program was used to make analysis of variance. And MSTAT statistical package program was used to make DUNCAN multiple comparative tests.

RESULTS

As a result of this research variation of average energy expenditure values of subjects according to the forward speeds were given at Figure 1, 2 and 3.

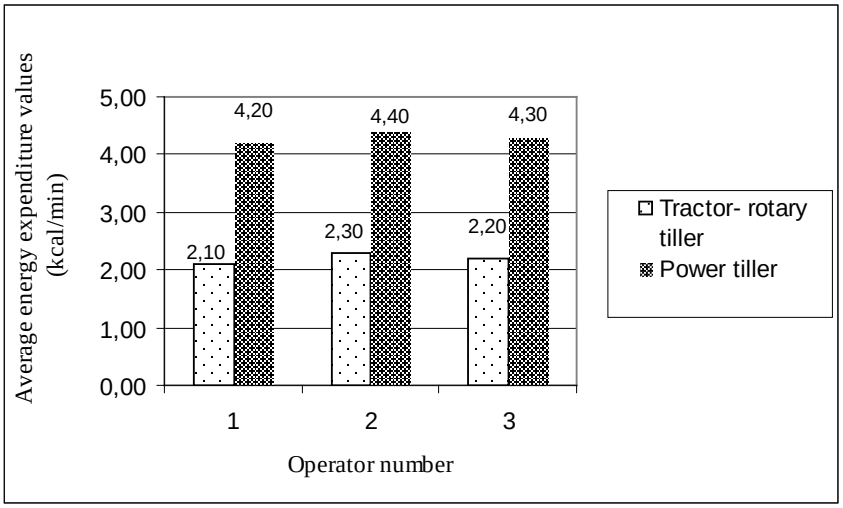

Figure3. Average energy expenditure values of subjects for working at 1.6km/h forward speed

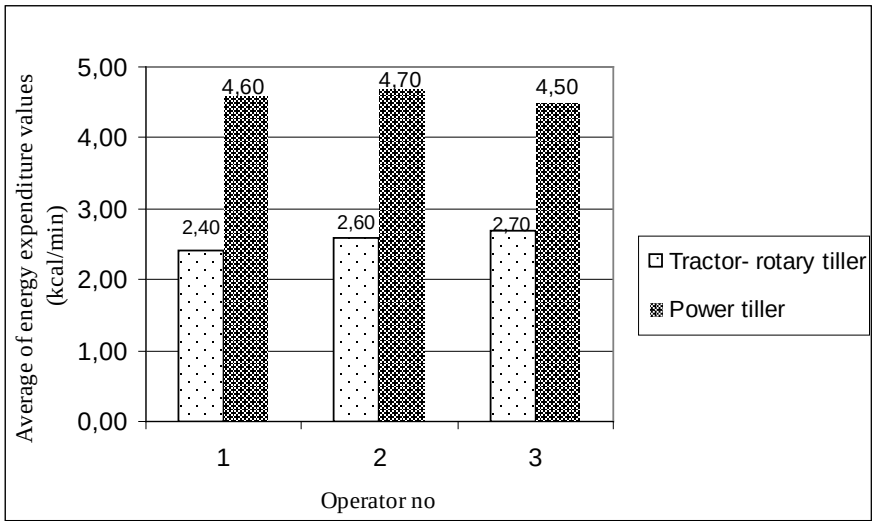

Figure4. Average energy expenditure values of subjects for working at 2.1km/h forward speed

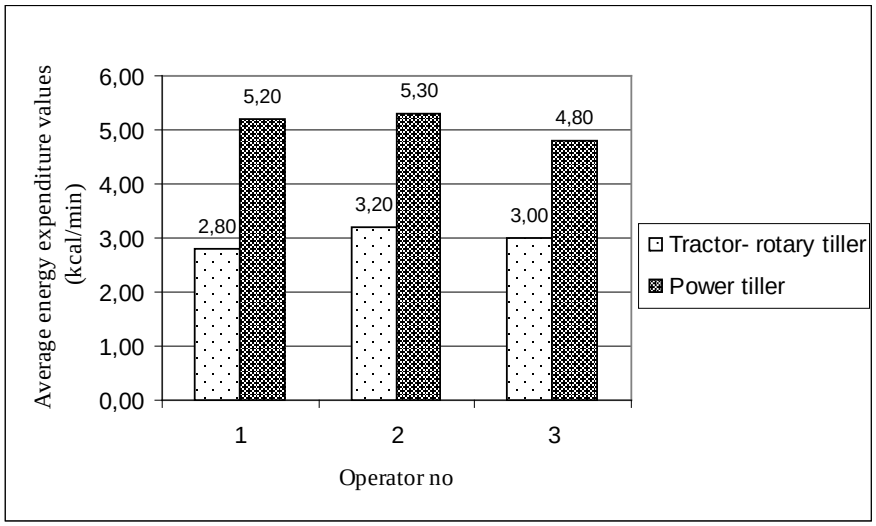

Figure5. Average energy expenditure values of subjects for working at 2.6km/h forward speed

Energy expenditure values of operators increase as increasing in forward speed with working with power tiller and tractor-rotary tiller combination. Energy expenditure values for working with power tiller are higher than working with tractor-rotary tiller combination at three forward speeds. Because operators must walk behind the power tiller and control the machine during hoeing operation. Also sharp turns at headlands and environment conditions are forced the operators. But, at working with tractor-rotary tiller combination operators try to follow a line to cultivate field smoothly. The most important difference between two types of operations is operators work sitting.

Working with a power tiller is in heavy work category. All energy expenditure values which belong to working with power tiller are higher than 4kcal/min. This value could be accepted like a threshold (Dinçer, 1977).

As a result of analysis of variance for energy consumption of operators, operator*type of machine interactions were statistically significant ($p<0.01$). The results were given at Table2. Results of DUNCAN test were given next to the mean values as letter representation.

Table2. Interaction between type of operation and operator factors (*Small letters were used to compare type of operation factors. **Capital letters were used to compare operator factors)

Operator no	Type of operation	
	Power-tiller $(\bar{x} \pm S_{\bar{x}})$	Tractor-rotary tiller $(\bar{x} \pm S_{\bar{x}})$
1	4.667±0.152 a B	2.433±0.110 b B
2	4.800±0.137 a A	2.700±0.133 b A
3	4.527±0.078 a C	2.638±0.127 b A

Energy expenditure values of operators are different for comparing type of operation. Also energy expenditure values of operators are different from each other for working with power tiller ($p<0.01$). But energy expenditure values of operator 2 and 3 could be acceptable same and operator 1 is different from other operators for working with tractor-rotary tiller ($p<0.01$).

Relation between retrieved energy expenditure values of subjects at three forward speed levels and forward speed were given at Table3.As understood average energy expenditure values of operators are different from each other for operation at various forward speeds.

Differences among the energy expenditure values for forward speed factor were found statistically significant ($p<0.01$). Results of DUNCAN test were given next to the mean values as letter representation.

Table3. Differences among the energy expenditure values for forward speed factor (*Small letters were used to compare forward speed factors)

Forward speed (km/h)	Energy expenditure values (kcal/min) $(\bar{x} \pm S_{\bar{x}})$
1.6	3.250±0.257 c
2.1	3.583±0.249 b
2.6	4.049±0.260 a

CONCLUSION

Based on the findings of these analyses;

Energy expenditure values of operators were increased with increase in forward speed for tilling operation with power tiller and tractor-rotary tiller combination.

Energy expenditure values for working with power tiller are higher than working with tractor-rotary tiller combination at all forward speed levels.

Energy expenditure value of each operator is different from others at working with power tiller.

This study indicated that working with power tiller is causing fatigue to operators. Operators exposed to these persistent factors arise from machine and environment during operation. The ability of workers to complete their work with less energy expenditure is one of main advantages in using agricultural machinery. As considered properties of enterprises such as purchasing power, repair and maintenance; if it is appropriate, using tractor-rotary tiller combination can be recommended instead of power tiller.

Future studies will be useful for farmers and researchers if includes aspect of agricultural management such as work efficiency, acquisition cost and maintenance cost.

REFERENCES

TUIK, 2006. Statistics of Agricultural Enterprises Structure. Available at: www.tuik.gov.tr Accessed 28 November 2009, Ankara, Turkey.

Babalik, F. C., 2005. Ergonomics for engineers (in Turkish), Nobel Publishing, 486 p., Ankara, Turkey.

Dinçer, H.,1977. Human and animal power in agriculture. (in Turkish) Ankara Üniversity Agricultural Faculty Publications Nr: 638, 137 p., Ankara, Turkey

Kang, D., Woo, J.-H., Shin, Y.-C., 2007, Distribution and determinants of maximal physical work capacity of Korean male metal workers, Ergonomics, 50: 2137-2147, Publisher Taylor & Francis, UK.

Malavolti, M., Pietrobelli, A., Dugoni, M., Poli, M., Romagnoli, E., De Cristofaro, P., Battistini, C. N., 2007, A new device for measuring resting energy expenditure (REE) in healty subjects, Nutrition, Metabolism & Cardiovascular Diseases,17: 338-343, Elsevier Publishing.

Müller, M. De L. and Coetsee, M. F., 2008. Physiological demands and working efficiency of sugarcane cutters in harvesting burnt and unburnt cane, International Journal of Industrial Ergonomics 38: 314-320, Elsevier Publishing.Silleli H., 2007. Research on applying an anchor mechanism to orchard and vineyard tractors produced in Turkey. Turkish Journal of Agriculture and Forestry, 31: 389-398,

Tiwari, S. and Gite, L.P., 2006. Evaluation of work-rest schedules during operation of a rotary power tiller. International Journal of Industrial Ergonomics, 36: 203-210, Elsevier Publishing.