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Design And Workload Analysis Bicycle-Powered Mobile Sprayer

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Abstract: The sprayer is a system capable of turning liquid into mist or solution. Based on spraying efficiency and spray field efficiency, sprayer performance can be evaluated. Parameters of spraying efficacy are in the form of droplet diameter and percentage of dead weeds, whereas efficiency of spraying field parameters are in the form of effective field capacity and theoretical field capacity. This research seeks to develop a bicycle-powered sprayer and, when used by farmers, to measure quantitative workload and qualitative workload. Workload analysis has been carried out with the heart rate parameter on the use of the knapsack sprayer, and both qualitative and quantitative workload will be considered. As observed participants, four males and four females were questioned. The Heart Rate Monitor (HRM) was used to record the heart rate during the operations. Previously, step test calibration was carried out for each subject in order to obtain individual HR-Workload correlations. The result shows that women have a higher qualitative workload than men, although there is no real difference in the quantitative workload for women and men. Subjects' work performance was also determined based on field capability and consumption of srayer fluid. The result showed that the energy consumption rate of women per hectare of work and per tank (20 liters) of spraying is much higher than that of men. Spraying activity using a knapsack sprayer is more appropriate for men (as a male job) compared to that for women, based on the results of the study.

KEYWORDS: mobile sprayer, bicycle powered sprayer, workload analysis

1. INTRODUCTION

Agricultural land in Indonesia has an area of 13 million ha. The presence of weeds in agricultural crops can reduce the supply of water, nutrients, sunlight and growing places for plants. Plants that lack the supply of these elements are unable to show maximum potential and yield. So that weeds can result in crop losses and cause financial losses. The potential loss varies depending on the type of plant, the type of weed and the growth factors that influence it (Chozin 2006).

Good practices in controlling weeds can maintain and improve the quality of the final crop. Consequently, there is a significant additional cost to run a weed control method. According to Utomo et al. (1986), the biggest component in handling weeds is labor costs. The component has a poris between 30 - 60% of the total cost of agricultural production.

Weed control can be done through physical, mechanical and chemical methods. Chemical methods use a mixture of chemicals that can inhibit the growth of weeds. In this method, a chemical mixture is called an herbicide, and the mixture is applied to plants and agricultural land using a sprayer (Moenandir 2002).

A sprayer is a device that is capable of turning a liquid or solution into very small and homogeneous droplets, which visually appear as mist. These changes (form and phase) are produced by liquid pressure and air pressure in the sprayer. Pressure on the sprayer is generated by a pump that pushes the liquid through the nozzle which changes the size and diameter of the droplet through the nozzle to form a mist or fine grain (droplet). In other models, pressure is generated by blowing air which pushes liquid through the nozzle to form a droplet.

Sprayer performance can be assessed based on the effectiveness of spraying and the efficiency of the spray field. Spraying effectiveness parameters in the form of a percentage (%) of initial weeds and dead weeds and droplet diameter, while the parameters of the spray field efficiency in the form of pressure, spray discharge, forward speed, effective spraying width (LPE), effective spraying height (TPE), output capacity (throughput capacity), Effective Field Capacity (KLE) spraying and Theoretical Field Capacity (TLC) spraying.

Application of herbicides using a sprayer can be improved field efficiency if spraying using a spray machine that can move quickly (mobile sprayer machine) and can increase the comfort of the operator (avoid the fatigue due to high noise and vibration) and further ease the operator in carrying a sprayer (weight sprayer + liquid) because it is mounted on a mobile sprayer machine. A mobile sprayer machine can be installed based on the principle of liquid pressure and air pressure, which is adopted by increasing the number of nozzles.

The power source used to operate the sprayer can be divided into two, namely a manual powered sprayer (hand sprayer) and a motor powered sprayer. The use of motor-powered sprayers has an advantage in performance, namely flexible droplet size regulation by changing the motor speed and compression of the sprayer tank. The greater the compression in the tank, the smaller the size of the resulting droplet (Malik et al, 2012). Another advantage is the volume of liquid sprayed can be minimized and the spraying time can be shortened.

Motor-powered sprayers can use power coming from tractors, but this method cannot be applied to high-farm agricultural land. Therefore, the use of sprayers in paddy fields is usually done using a sprayer carrying (knapsack sprayer). The use of knapsack sprayers in pest and plant disease control activities requires farmers as operators to carry loads in the form of pesticide and motor solution tanks. These activities cause fatigue due to physical workload that is too heavy that exceeds the capacity of the ability of the human body. Accumulated fatigue can cause a person to feel sick or even suffer an injury.

One form of manual sprayer-powered manual sprayer sprayer appliance is to apply the frame and wheels and be operated by being pushed. The thrust-type sprayer utilizes wheel rotation (rotation) into up and down (translational) movements that pump air into the tank so that it produces high pressure, and can compress the liquid that comes out to penetrate the nozzle and into small-sized water droplets (droplets).

Improvements to the design of the sprayer with the thrust type need to be followed by measurements of the workload. The workload can be measured quantitatively through energy consumption, or qualitatively through measurements based on heart rate. According to Bridger (2003) heart rate is influenced by operator activity and workload.

This study aims to design a bicycle-powered sprayer and measure quantitative workloadand qualitative workload when used by farmers.

2. RESEARCH METHODS

The bicycle powered sprayer is designed based on the working principle of the knapsack sprayer combined with a trolley consisting of a frame and wheels. The main principle of a bicycle powered sprayer is to change the pumping mechanism of the knapsack sprayer which is done by hand movement into an automatic mechanism. The pumping mechanism utilizes the wheel rotation energy when the bicycle is being pushed. This mechanism is applied by utilizing the gird and chain to connect the pump trigger rod with the pump lever and trolley wheel. So that the mechanism system can change the rotation of the wheels into translational motion at the pump tank. The design of a bicycle powered sprayer is shown in Figure 1.

Figure 1. Design of bicycle powered sprayer

The performance of a bicycle powered sprayer is measured by the effectiveness of the spraying and the efficiency of the spray field. The parameters of spraying effectiveness can be droplet diameter and percentage of initial weeds and dead weeds while the spray field efficiency parameters can be in the form of effective field capacity and theoretical field capacity. Spraying is done by mixing the herbicide with water using a power sprayer knapsack and mist blower mounted by mounting the number of nozzles then connected to the pedal and bicycle gear mechanism.

Workload analysis is performed using farmer's physical parameters in the form of heart rate, which subsequently obtained qualitative and quantitative workload values. Measurements using heart rate parameters are carried out using a Heart Rate Monitor (HRM) tool. In the measurement of workloads, the step test calibration is first performed with the aim of finding out the correlation of increased heart rate to the increase in workload of each subject. Step test activities are carried out using a step test bench with a height of 25 cm. The step test data collection is carried out in stages with three frequencies, namely: 15 steps / minute, 20 steps / minute, and 25 steps / minute. From the calibration using the step test method, the correlation between Increase Ratio of Heart Rate (IRHR) and Work Energy Cost (WEC) was obtained.

3. RESULTS

3.1 Measurement of Discharge and Pressure

Discharge is a measure that shows the amount of liquid that comes out of the nozzle per unit time. The discharge generated at the sprayer also depends on the gas pressure applied. In this study the discharge is measured by storing the liquid that comes out of the nozzle into the measuring cup, while the gas pressure is measured by a pressure gauge. The measurement results show the discharge that came out at the nozzle was 4.17 liters / minute with a pressure of 8.6 kgf / cm2.

3.2 Measurement of Droplet Size

A droplet is a measure of water droplets sprayed from a nozzle. Droplets are measured by filling the solution with a colored substance and spraying it on a piece of paper. The paper is then scanned and processed with graphic software to determine the size of the sprayed grain. The results showed that the sprayed droplet had a diameter of 330 micrometers to 365 micrometers.

3.3 Measurement of Spraying Width

Spraying width is the furthest range of water particles sprayed by the nozzle in a plane. The width of the spraying is measured by filling the sprayer tank with color and spraying it on a 100cm x 100 cm paper. The paper is then scanned and processed with graphical software to determine the wetted area. The maximum effective spraying width of a liquid pressurized sprayer is 1.36 m.

3.4 Measurement of Working Speed

Working speed shows the measure of time needed to travel the work track at a certain distance. In this study the work trajectory was determined as far as 10 m. Working speed is obtained by dividing the distance with the time required.

3.5 Measuring the Increase Ratio of Heart Rate (IRHR)

IRHR is a comparison between a person's heart rate when performing an activity and when resting. Heart rate measurements are carried out with the help of sensors and manual calculations, before the operator operates the sprayer and after the operator operates the mobile sprayer.
Heart rate data acquisition for HR work is taken after the third minute and before the last two minutes. It is intended that the data obtained is valid data. Just like when doing a step test, the subject in the early minutes experiences an anaerobic phase, so it is not advisable to take data in the early minutes, whereas at the last minute the worker has not followed the work pattern as expected, so that the data obtained is less so good. For IRHR values when spraying activity is obtained by comparing the average value of HR work with HR rest. Examples of calculation of HR and IRHR values are as follows (subject P1) and IRHR values in each subject can be seen in Table 1.

Table 1. IRHR values for spraying activities

Subject	HR rest	HR W1	HR W2	HR W3	IRHR W1	IRHR W2	IRHR W3	**IRHR Average**
F1	88.50	151.00	160.00	161.00	1.706	1.808	1.819	**1.778**
F2	66.83	140.67	142.00	130.17	2.105	2.125	1.948	**2.059**
F3	100.33	155.83	161.67	162.14	1.553	1.611	1.616	**1.594**
F4	88.50	162.29	154.00	163.29	1.834	1.740	1.845	**1.806**
M1	79.33	116.43	120.50	117.33	1.468	1.519	1.479	**1.489**
M2	71.17	122.33	122.00	123.50	1.719	1.714	1.735	**1.723**
M3	80.43	138.33	132.00	133.00	1.720	1.641	1.654	**1.672**
M4	73.33	125.33	125.33	128.67	1.70	1.709	1.75	**1.724**

		9	5

The highest average IRHR value was found in female subjects with a standard deviation of 0.1912 and higher when compared to men. High standard deviations indicate more varied data when compared to data that have low standard deviations. The physiological responses of female subjects are more varied than males, because the burden felt by each female subject is very much different. In addition, habits and skill levels among female subjects also vary.
The average IRHR value is obtained from averaging the IRHR value of Repetition 1, Repetition 2, and Repetition 3. From the average IRHR value it can be seen that the IRHR value of female subjects is greater than male subjects. This can also be seen from the clarity of the subject. The clarity of each subject can be seen from the IRHR value. Furthermore, the IRHR value of each subject is classified according to Table 3. The qualitative workload of male subjects is classified in the moderate to heavy category, whereas in female subjects the heavy to unusually heavy, so this work is more tiring for female subjects. In general, physical men are stronger than women, so the ability to accept a higher burden of men when compared to women. Categories of lucidity of each subject can be seen in Table 2.

Table 2. IRHR scores and subject's qualitative workload

Subject	IRHR average per subject	Qualitative Workload	**IRHR Arage**	**Standar deviation**	**Average Qualitative Workload**
F1	1.778	Very Heavy	**1.809**	**0.1912**	**Very Heavy**
F2	2.059	Extraordinry Heavy			
F3	1.594	Heavy			
F4	1.806	Very Heavy			
M1	1.489	Moderate	**1.652**	**0.1113**	**Heavy**
M2	1.723	Heavy			
M3	1.672	Heavy			
M4	1.724	Heavy			

3.6 Measurement of Work Energy Consumption (WEC)

Work energy is the energy that must be released by the body when doing a work activity. WEC values for each subject can be seen in Table 3. WEC, TEC, and TEC values are directly proportional. So the higher the WECWORK value, the TEC and TEC values will also be higher. Each subject does the same job, which is spraying rice plants using a knapsack sprayer. However, it can be seen in Table 10, the physiological responses of each subject differ. There are several factors that influence these differences including the characteristics of each subject, physiological abilities (cardio-vascular / heart and muscle fiber abilities) of each subject, and the influence of the physical environment (temperature and humidity). Subject P2 has a lower TEC value than the others, this is because subject P2 has a very low weight, so the burden felt for him is relatively lower when compared to the others.

Table 3. Value of energy consumption when spraying

Subject	Bodyweight (kg)	WEC work (kkal/min)	BME (kkal/min)	TEC (kkal/min)	TEC' (kkal/kg bw. min)
F1	52	3.06	0.869	3.929	0.076

		0			
F2	37	1.632	0.770	2.402	0.065
F3	47	2.254	0.865	3.119	0.066
F4	66	2.444	0.998	3.442	0.052
		Average		**3.223**	**0.065**
M1	61.5	2.072	1.010	3.082	0.050
M2	58	2.702	1.045	3.747	0.065
M3	52	2.608	0.970	3.578	0.069
M4	50	2.684	0.990	3.674	0.073
		Average		**3.520**	**0.064**

4. CONCLUSION

The bicycle powered sprayer is designed based on the working principle of the knapsack sprayer combined with a trolley consisting of a frame and wheels. The main principle of a bicycle powered sprayer is to change the pumping mechanism of the knapsack sprayer which is done by hand movement into an automatic mechanism. The pumping mechanism utilizes the wheel rotation energy when the bicycle is being pushed. This mechanism is applied by utilizing the gird and chain to connect the pump trigger rod with the pump lever and trolley wheel. So that the mechanism system can change the rotation of the wheels into translational motion at the pump tank.

The measurement results show that the discharge came out at the nozzle was 4.17 liters / minute with a pressure of 8.6 kgf / cm2. The results showed that the sprayed droplet had a diameter of 330 micrometers to 365 micrometers.The highest pressure liquid discharge sprayer is 4.17 liters / minute. The maximum effective spraying width of a liquid pressurized sprayer is 1.36 m.

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REFERENCES

Aspar G. 2012. Studi aplikasi *knapsack sprayer*, *knapsack power sprayer,* dan *boom sprayer* di PT Laju Perdana Indah, Palembang, Sumatera Selatan [skripsi]. Bogor (ID): Institut Pertanian Bogor.

Badan Standarisasi Nasional. 2008. SNI *Sprayer* Kompresi Tipe Gendong-Unjuk Kerja dan Cara Uji. Jakarta (ID) : BSN.

Badan Standarisasi Nasional. 2012. SNI-4513-2012. *SNI Alat Pemeliharaan Tanaman Sprayer Gendong Semi Otomatis Syarat Mutu dan Metode Uji*. Jakarta (ID) : BSN.

Bridger RS. 2003. Introduction to Ergonomics. Taylor & Francis. London & New York.

Chozin MA. 2006. Peran ekofisiologis tanaman dalam pengembangan teknologi budidaya pertanian. Orasi Ilmiah Guru Besar Tetap Ilmu Agronomi. Faperta IPB. 114 hlm.

Daywin FJ, Sitompul RG, Imam H. 1992. Mesin-Mesin Budidaya Pertanian. Bogor (ID): JICA-DGHE/IPBProject.

Dwigiarti A. 2009. Analisis Tingkat Resiko Ergonomi Berdasarkan Aspek Pekerjaan di Bagian Assembling G-Line pada Pekerja Instrumen Panel PT. Indomobil Suzuki Internasional Plant Tambun II, Bekasi Tahun 2009. [skripsi]. Jakarta: Fakultas Kedokteran dan Ilmu Kesehatan, Universitas Islam Negeri Syarif Hidayatullah.

Field LH, Solie BJ. 2007. *Introduction to Agricultural Engineering Technology*.

Furqon M. 2012. Studi variasi jumlah dan ukuran droplet pada berbagai tinggi penyemprotan dan tipe nosel *sprayer* gendong semi-otomatis [skripsi]. Bogor (ID): Institut Pertanian Bogor.

Guntoro D, Karlin A, Yursida. 2013. Efikasi herbisida Penoksulam pada budidaya padi sawah pasang surut untuk intensifikasi lahan suboptimal. *Jurnal Lahan Suboptimal*. 2(2): 144-150.

Hardjosentono M, et al. 1978. Mesin-Mesin Pertanian. Jakarta: C. V. Yasaguna.

Harefa T. 1997. Pengaruh Tekanan, Panjang Selang, dan Dosis Herbisida Terhadap Jumlah dan Ukuran Diameter Butiran pada Alat Semprot (Sprayer) Bertenaga Traktor Tangan. [skripsi]. Bogor: Fakultas Teknologi Pertanian, Institut Pertanian Bogor.

Hermawan W. 2012. Kinerja sprayer bermotor dalam aplikasi pupuk daun di perkebunan tebu [ulasan]. *JTEP*. 26(2): 93-94.

Herodian S, Lenny S, Kusen M. 1999. Panduan Praktikum Ergonomika. Bogor: The Faculty of Agricultural Engineering and Technology Bogor Agricultural University (IPB).

Kadir M. 2007. Efektivitas berbagai dosis dan waktu aplikasi herbisida 2,4 Dimetilamina terhadap gulma *Echinochloa colonum*, *Echinochloa cruss- galli*, dan *Cyperus iria* pada padi sawah. *Jurnal Agrisistem.* 3(1).

Kastaman R dan Sam Herodian. 1998. Studi Kalibrasi Data Pengukuran Beban Kerja dengan Menggunakan Metode Step Test dan Ergometer. Bul Keteknikan Pertanian 12(1) : 35-45.

Kroemer KHE dan E.Grandjean. 1997. Fitting the Task to The Human, (5th ed). London : Taylor and Francis.

Lovita. 2009. Analisis Beban Kerja Pada Pembuatan Guludan di Lahan Kering. [skripsi]. Bogor: Fakultas Teknologi Pertanian, Institut Pertanian Bogor.

Madkar OR, Kuntohartono S, Mangoen-soekardjo. 1986. Masalah Gulma dan Pengendalian. Bogor (ID): Balai Pertanian Tanah.

Moenandir. 2002. Ilmu Gulma dalam Sistem Pertanian. Bogor (ID): Balai Pertanian Tanah.

Srivastava AK, Goering CE, Rohrbach RP. 1993. *Engineerig Principles of Agricultural Machines*. Michigan: American Society of Agricultural Engineering.

USA (ID): Springer.

Utomo IH, Lontoh P, Rosilawati, Handaya. 1986. Kompetisi Teki dan Gelang dengan Tanaman Hortikultura. Prosiding Konferensi VIII HIGI. Bandung (ID): Balai Pertanian Tanah.

Verma AK, Dewangan ML. 2006. Efficiency and Energy use in puddling of lowland rice grown on vertisols in central India. *Journal of Soil and Tillage Research* 90:100-107.