Journal of Engineering, Technology & Applied Science
p-ISSN: 2721-7949, e-ISSN: 2721-8090

Original Research Paper

Ergonomic Evaluation of Anthropometry Based Hydroponic Plants Watering Automation System

Ahmad Hanafie[1], Andi Haslindah[1], Suradi[1], M. Ansyar Bora[2], Syarifuddin Baco[3]

[1] *Departement of Industrial Engineering, Universitas Islam Makassar. Makassar, Indonesia.*
[2] *Departement of Informatics Engineering, Universitas Islam Makassar. Makassar, Indonesia.*
[3] *Department Engineering Management, Institut Teknologi Batam. Batam, Indonesia.*

Article History
Received:
25.10.2022

Revised:
19.10.2022

Accepted:
03.11.2022

***Corresponding Author:**
Ahmad Hanafie
Email:
ahmadhanafie.dty@uim-makassar.ac.id

Abstract: Hydroponics is a technique of growing plants without soil. Until now, many people do it manually for moisture, content, nutrition, and continuous flow of water. The application of ergonomics aims to make the user healthy, comfortable, safe, productive. The purpose of evaluating anthropometry-based ergonomics, and testing the hydroponic plant watering automation system tool. The method used is collecting anthropometric data on the dimensions of the user's body for ergonomics, then designing an automatic hydroponic watering tool to make it easier to design hardware and software. The results of the ergonomics evaluation study, hand span size 175.3 cm, upright body height 167.4 cm, shoulder to head 32.23 cm, shoulder to base of foot 66.77 cm, base of foot to knee 48.89 cm, base of foot to knee 48.98 cm, elbow to elbow 41.81 cm, elbow to hand 34.45 cm. While the results of testing the condition of the charcoal are at the humidity threshold of 49% - 60% then the pump will be on, and if the pot has been on the humidity threshold of 65% - 99% then the pump will be off.

Keywords: Anthropometry, Arduino, Automatic, Ergonomics, Watering Plants.

Journal of Engineering, Technology & Applied Science, vol. 4, no. 3, pp. 122-130, August 2022. **DOI: 10.36079/lamintang.jetas-0403.463**

1. Introduction

The aim and objective of the ergonomics discipline is to gain a complete knowledge of the problems of human interaction with technology and its products, so that it is possible to have an optimal human-human (technology) system design. Thus the discipline of ergonomics sees the interaction problem as a system. Ergonomics sees the interaction problem as a system by solving the problem through a process approach as well [1].

Ergonomic potential problems will be found in every system, where human users have a role in the success of the system in achieving its goals. The implementation of ergonomics in the workplace is expected to have an impact on both individual and organizational goals simultaneously. Important benefits that can be obtained include increasing work productivity, improving process and product quality, and work satisfaction levels [2]. The need for food for humans such as vegetables and fruits is increasing along with population growth, this is not closely related to the growth of agricultural land which is increasingly scarce in practice. Because it is inevitable to convert land into settlements in big cities, as well as on an agricultural scale, the hydroponic system is the best solution to address nutritional problems in the agricultural business module [3].

Hydroponic media requires electricity to circulate water into a pipe with a water pump. Then to save power, users can use a controller that can change the on and off time with a current regulator. Automatic control makes it easy for the user to turn the power on and off, this is done using a submersible pump connected to the controller. For the controller to move to the pump and the nutrient solution is pumped into the media when the system and timer stop the pump, the solution will flow again to the shelter. Arduino has been programmed according to the needs according to its users, with this we can find out the voltage contained in Arduino [3].

Previous research one of the weaknesses of the hydroponic axis system is that the nutrient solution does not circulate so it is prone to moss growth, plant growth is slightly slower. This can be overcome by combining it with a hydroponic axis system with NFT. The results for the Lollo Rossa variety of lettuce have a very large effect on fresh weight parameters and plant growth rate, and have a large effect on leaf volume parameters. Parameters of plant height, number of leaves, application of CaCI2 greatly affect the variable volume of lolo rosa lettuce leaves, fresh weight and growth rate [4].

Water pumps usually require continuous electric power, thus making automatic water pumps in hydroponic plants, which aim to increase the efficiency of the electric power pump for hydroponic media water pumps. This tool is also equipped with an LCD (Linquid Cristal Display) which shows the condition of the soil wet or dry based on the readings of the humidity sensor, depending on the pH of the charcoal that needs to be regulated by the plants, with this tool you don't have to water the plants manually every day, this watering tool can be used for people who have a hobby of growing plants in the yard of the house or arranging them in other places that are closed, and this tool is designed according to the user's body posture by using ergonomic body dimensions with an anthropometric approach. As for this study, the aim was to evaluate the results of an ergonomic hydroponic plant sprinkler design based on anthropometry, and then to test the hydroponic plant watering automation system tool.

2. Literature Review

2.1. Ergonomi

Ergonomics actually comes from the Greek, word Ergo which means work and nomos which means law. Thus, ergonomics is intended as a scientific discipline that studies humans in relation to workmanship [1].

Ergonomics which means a rule or rule that is obeyed in the work environment [5]. Ergonomics is a science from other multidisciplinary learning that bridges several disciplines and professionals, and summarizes information, findings, and principles from each of these disciplines. The sciences in question include physiology, anatomy, psychology, physics, and engineering. Human activities require energy, the amount of which depends on the size of the workload and the physical abilities of each individual [6].

The focus of ergonomics is closely related to the human aspects of planning and the work environment. Systematically, an ergonomic approach will then utilize this information for design purposes, so as to create products, work systems and work environments that are more suitable for humans. In turn, ergonomic work design will be able to increase work efficiency, effectiveness and productivity, and can create systems and work environments that are suitable, safe, comfortable and healthy [1].

Journal of Engineering, Technology & Applied Science, vol. 4, no. 3, pp. 122-130, August 2022. **DOI: 10.36079/lamintang.jetas-0403.463**

Anthropometry is a collection of numerical data related to the physical characteristics of the human body, size, shape and strength and the application of these data for handling design problems. The application of this anthropometric data will be possible if the average value and standard deviation of a normal distribution are available. The normal distribution is characterized by the existence of an average value and a standard deviation. Meanwhile, percentile is a value which states that a certain percentage of a group of people whose dimensions are equal to or lower than that value [6].

2.2. System

The system as a collection of elements that work together to achieve a certain goal. The systems approach which is a collection of elements, components or subsystems is a stronger definition and is widely accepted because a system is actually made up of multiple subsystems. But the views of Japerson Hutapea, Jerry Fitz Gerald, Arda F. Fitz Grald, Warren D Stalling Jr, Jogiyanto HM, stated "The system is a network of products that are closely related, come together in carrying out a form of activity or for a particular problem [7].

2.3. Automation

Automation is the replacement of human power by machine power by machine power that automatically performs and manages human work in industry and so on [8]. Automation is a word that comes from the Ford Motor Company to express an automatic and directed movement from one activity to the next. Automation describes the movement of materials in process or parts from one machine to the next automatically which is selective where there is a feedback system. The feedback system in automation allows the machine to sense, find and correct errors that arise when goods are processed or made on the machine.

2.4. Hydroponic

Hydroponics is a way of farming without using soil as a planting medium, but using water that contains the nutrients plants need [9]. Therefore, using this method it will be easier to control the effects of pests, diseases and light that commonly affect plants. Plants grown using hydroponics are very environmentally friendly methods, because cultivating does not need to use toxic pesticides or herbicides. These systems utilize water for growth, but in reality they don't need as much water for agriculture as they do for convection growth. Several previous studies; The results of the study obtained the effect of mixed planting media between husk charcoal and rice husk, rice husk with fern roots and husk charcoal with fern roots on the growth of mustard greens hydroponically. The results of the study included 3 treatments and 3 different concentrations, each repeated 4 times each up to 48 observations. Process 1 charcoal + rice husk, 75% + 25%, 50% + 50%, 25% + 75, 4 times, treatment II rice bowl + fern root, respectively 75% + 25%, 50% + 50%, 25% + 75%, control shell charcoal, rice husk and fern root with only 4 literacy. Parameter values of plant height, number of leaves, leaf length and root length were calculated 0, 7, 14, 21, 28 days (DAP) after planting [10].

This research resulted in the nRF24L01 + transceiver with external antenna and soil moisture sensor V2SEN0114 being used as a wireless sensor component to develop a soil moisture monitoring system in agriculture. This sensor uses two conductors to transmit electric current to the ground and reads the resistance value to receive the humidity level. Due to the convenience of this wireless sensor, information on the soil moisture sensor V2SEN0114, collecting moisture results, is wirelessly transmitted from the nRF 24 L01+ transceiver to the LCD, so farmers are in one place to measure soil moisture. Necessary, at the location of the base station. [11].

3. Methodology

The implementation of the research was carried out in two stages. The first stage is collecting anthropometric data by measuring the dimensions of the user's body for 100 respondents including the influential body dimensions are Arm Span, Height Upright, Shoulder to Head, Shoulder to Base of Foot, Base of Foot to Knee, Knee to Floor, Elbow to Elbow, Elbow to Hand, followed by statistical testing. This test was carried out at the Work Design Analysis and Ergonomics laboratory of the industrial engineering study program - Islamic University of Makassar. The data uniformity test is uniform if the data is between Upper Control Limit and Lower Control Limit using 95% confidence level and 5% accuracy level [12].

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$$UCL - \bar{X} + 2\sigma_c$$ Equation 1

The upper control limit (UCL) is the highest limit data value in the data uniformity test.

$$LCL = \bar{X} - 2\sigma_c$$ Equation 2

The lower control limit (LCL) is the lowest limit data value in the data uniformity test.

$$\sigma = \sqrt{\frac{\Sigma(x_i - x)^2}{N-1}}$$ Equation 3

Standard deviation is the statistical value used to determine how data is distributed in a sample.

$$\sigma x = \frac{\sigma}{\sqrt{n}}$$ Equation 4

Sub-group standard deviation is a measure used to measure the amount or distribution of several data values in a sub group. Test Data adequacy, good to know enough data or not with condition N ' < N, with 95% confidence level and level of accuracy 5% [13] [14].

$$N' = \left[\frac{K / S\sqrt{N\sum X_i^2 - \left(\sum X_i\right)^2}}{\sum X_i} \right]^2$$ Equation 5

Test the percentile test using the normal distribution and calculating percentiles [15] [16], with the formula:

Percentiles 5 % = $\bar{X} - 1.65\ \sigma_x$ Equation 6

Percentiles 50 % = $\bar{X}$ Equation 7

Percentiles 95 % = $\bar{X} + 1.65\ \sigma_x$ Equation 8

The second stage was in the Computer Laboratory of the informatics engineering study program - Makassar Islamic University, the system planning research method was built by designing hardware and software using modules, namely Arduino uno and humidity sensors, LCD, temperature sensors, water pumps, aquarium, water PH meter, relay, adapter, and jumper cables, as well as the Arduino IDE as the software. The working method of this tool is to plug the humidity sensor into a pot containing charcoal, which will later read the condition of the low or dry charcoal, then the information read by the sensor will be displayed on the LCD, if the charcoal is dry then the information on the LCD will be sent to the Arduino UNO to turn on the pump that will deliver water to the plants.

4. Finding and Discussion

4.1. The results of an Ergonomic Design Based on Anthropometry

The results of observations with an anthropometric approach that affect the ergonomic hydroponic plant watering automation system, will be carried out a series of statistical tests. The results of the data uniformity test using the upper control limit and lower control limit, if the average sub-group data is between these two limits, then the data is declared uniform data. The results of the data uniformity test for measuring body dimensions using Equations (1) (2).

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Table 1. Shows the body dimensions related to the hydroponic plant automatic sprinkler design, the observational data obtained is between the upper control limit and the lower control limit, so it can be said that the data is uniform.

Table 1. Body Dimension Data Uniformity Test Results

No.	Body Dimension	UCL (cm)	LCL (cm)
1	Hand Range	176.59	162.25
2	Upright Height	168.00	161.02
3	Shoulders to Head	32.53	29.09
4	Shoulder to Leg	61.32	55.06
5	Base of Leg to Knee	49.39	43.66
6	Knee to Floor	49.53	43.28
7	Elbow to Elbow	42.84	31.32
8	Elbow to Hand	34.77	31.13

The results of the data adequacy test for measuring body dimensions were measured using Equation (5), namely:

Table 2. Results of Body Dimensions Data Adequacy

No.	Body Dimension	N	N'
1	Hand Range	100	1.75
2	Upright Height	100	0.44
3	Shoulders to Head	100	3.07
4	Shoulder to Leg	100	2.84
5	Base of Leg to Knee	100	3.68
6	Knee to Floor	100	4.44
7	Elbow to Elbow	100	23.7
8	Elbow to Hand	100	2.33

Table 2. Shows the dimensions of the body related to the design of the automatic sarong folding device that meets the adequacy of the amount of observational data obtained with the result that is N' < N as a condition in determining the data adequacy test. The results of the Percentile Test by measuring the 95% percentile (95%-ile) for measuring body dimensions that affect it using equation (8) while the results are as shown in table 3, namely:

Table 3. Percentile Test Results

No.	Body Dimension	95%-ile (cm)
1	Hand Range	175.3
2	Upright Height	167.4
3	Shoulders to Head	32.23
4	Shoulder to Leg	66.77
5	Base of Leg to Knee	48.89
6	Knee to Floor	48.98
7	Elbow to Elbow	41.81
8	Elbow to Hand	34.45

Table 3. Shows the results of the 95% percentile test for body dimensions related to watering hydroponic plant automation, the size to be used in an automatic plant watering system for hydroponic plants is the 95% percentile, as a reference in determining an ergonomic watering tool so that it can be

used safely and comfortably [17]. The results are as follows: The width of the plant media, the body dimensions used for the vulnerable hand is 175.3 cm, The height size for the plant media, the body dimensions are used for upright height 167.4 cm, The distance between the plant media and the watering position, the body dimensions are used shoulder to head 32.23 cm, Size for the distance between the planting media and the pole connection, body dimensions used shoulder to the base of the foot 66.77 cm, Size for the distance between the planting medium and the first pole connection with the second pole, body dimensions used from the base of the leg to the knee 48.89 cm, The size for the distance between the planting medium and the connection between the first pole and the second pole, the body dimensions used from the base of the foot to the knee 48.89 cm, The size for the distance between the first watering and the second watering, body dimensions used elbow to elbow 41.81 cm, The size for the left and right leg holders, the body dimensions used by the elbow to the hand are 34.45 cm.

4.2. Design of Automatic Sprinklers

The results of the evaluation of the ergonomics of the hydroponic plant watering automation system based on anthropometry have been carried out, so the next step is to design an automation system program using Arduino uno with Arduino IDE programming and a humidity sensor which is a tool design to regulate temperature and humidity in the soil.

The design of this hydroponic plant maintenance automation system is an automatic watering device. The first step is to prepare the tools and materials to be used then prepare the Arduino UNO mainboard, the second step is to place the electronic components so that they can make it easier to customize the current system. The next process is to make a schematic of the plant watering system automatically to a location where the Arduino uno is connected to several other components such as a YL-69 humidity sensor, temperature sensor, LCD, relay, water pump and several other components. Making a hydroponic plant watering system using humidity and temperature sensors includes several stages of manufacture. Starting with preparing the materials and tools used. Like making a circuit that will be used as a test site. This simulation tool is based on time input which is processed by Arduino uno and the results come out connected to a relay, which aims to control the water pump automatically.

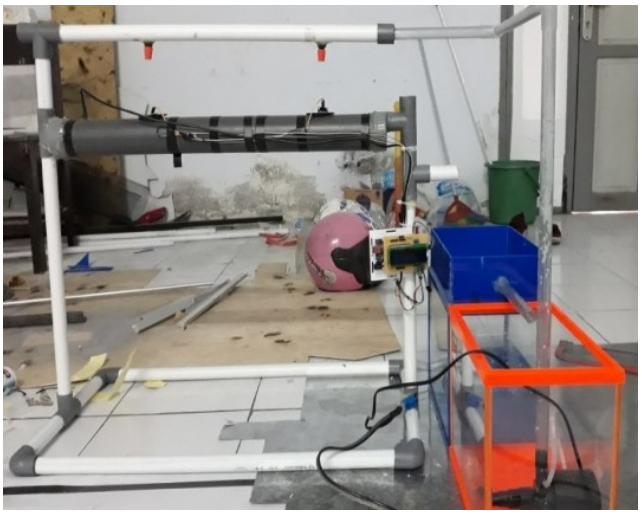


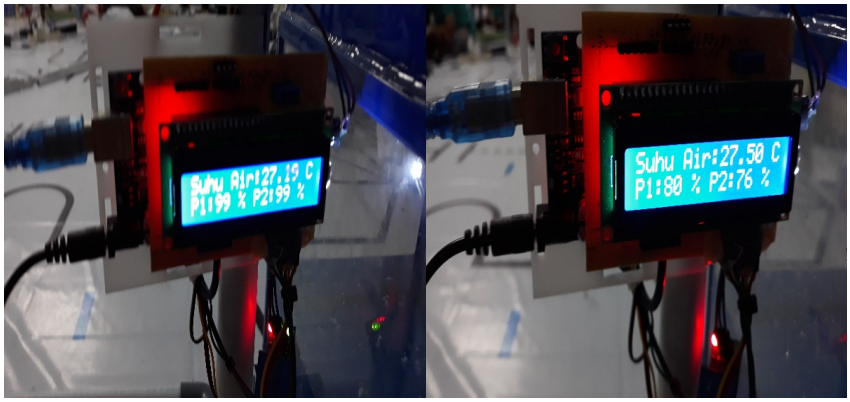
Figure 1. Design of an Ergonomic Plant Sprinkler based on Anthropometric Dimensions

4.3. Tool Testing Results

Tool testing is a test that is carried out on circuits that have been designed to test their performance. This test is carried out to analyze the level of success of the tool to work properly according to the functions of each component, first the sensor test is carried out for the sensor transmission method, connected to a signal generator, in order to know the humidity and temperature in the pot containing

the plant, from the measurement of the two conditions it is obtained that the charcoal has moisture that is not wet and the charcoal that has moisture that is wet or not dry.

In the picture below the test shows the setting or temperature and humidity for the plant waterer. Electronic time temperature and humidity sensors measure time and temperature and are processed by Arduino Uno, so setting the time for watering plants has a button that allows you to set the time according to the watering schedule we have made.



(a) (b)

Figure 2. Temperature and Humidity Sensor Testing
a) Wet testing
b) Dry testing

Table 4. Shows the sensor reading test results displayed. The sensor test results show that the sensor will turn on if the humidity threshold in the charcoal is around 49% - 60% then the pump will turn on and flush, and if the humidity threshold on the charcoal shows 64% - 99% then the pump will automatically turn off. Conversely, if the humidity threshold in a normal pot is around 74% - 99%, the device does not water or the pump will remain in a dead condition. So from the test results on the sensor, it shows that this system is capable and effective in automatically watering plants and humidity sensors that the watering process is carried out with the pump running from the percentage of humidity shown on the charcoal so that watering can be done according to a predetermined time. This shows that all the devices in this system have succeeded and achieved the desired goals and can see changes in temperature displayed on the LCD.

Table 4. Testing of Humidity and Temperature Sensors

No.	Time	Temperature (°C) in LCD	Humidity in LCD	Pump
1.	21.00	32,50 °C	99%	Off
2.	19.00	30,50 °C	80%	Off
3.	17.00	28,50 °C	76%	Off
4.	16.00	27,19 °C	64%	Off
5.	15.00	26,50 °C	60%	On
6.	14.00	25,50 °C	57%	On
7.	12.00	23,50 °C	49%	On

This automatic tool test was carried out when watering hydroponic plants for one week, three times a day. According to the condition of the charcoal in the pot, if the water in the pot shrinks and the charcoal becomes dry, the tool will do the watering. However, overall the humidity in the charcoal in the pot can vary depending on the temperature around the hydroponic plants, so watering is done at a

certain time so as not to overwater. Based on the test results, this tool has weaknesses including the delay that occurs for 5 minutes in receiving messages from Arduino Uno, this is due to a slight problem when receiving data to Arduino Uno.

4.4. Discussion

The results of an ergonomic evaluation based on anthropometry using the 95% percentile, which means that out of the 100 respondents who conducted this study, around 95% of the respondents were able to use this design tool according to body dimensions, meaning that its use in carrying out activities will increase work productivity, which can be reduced is feeling tired in carrying out the activity of controlling the hydroponic plant watering device. Optimization of body dimensions in tool design has been adjusted to the user.

The automatic watering system for this plant uses a soil moisture sensor but is placed on charcoal in a hydroponic pot, hydroponic planting does not use soil media but only uses water because the basic concept of this tool is a type of farming or plant maintenance that uses water as a nutrient medium, absorbed by plants directly to support their growth.

The moisture level of the charcoal in the pot can be detected using a soil moisture sensor. The humidity sensor is planted in a pot that is in the hydroponic device and also contains charcoal, the temperature sensor is plugged into the paralon pipe which is part of the pot, these two sensors will regulate the amount of water and indicate that the charcoal in the pot is wet or dry, if in conditions wet then the pump is off while if it is dry then the pump will turn on.

5. Conclusion

The results of the study were based on ergonomic evaluation, the width of the plant media, the dimensions of the body used were vulnerable hands 175.3 cm, the height of the plant media, the body dimensions were used upright height 167.4 cm, the distance between the plant media and the watering position, the body dimensions were used by the shoulders to head 32.23 cm, Size for the distance between the planting medium and the pole connection, body dimensions used shoulder to the base of the foot 66.77 cm, Size for the distance between the planting medium and the first pole connection with the second pole, body dimensions used the base of the foot to the knee 48.89 cm, Size for the distance between the planting medium and the connection of the first pole with the second pole, body dimensions used from the base of the foot to the knee 48.98 cm, Size for the distance between the first watering, and the second watering, body dimensions used elbow to elbow 41.81 cm, Size for left and right foot support, body dimensions used elbow to hand 34.45 cm.

This automatic watering tool for hydroponic plants uses a soil moisture sensor to be placed on the charcoal so that it can read the condition of the charcoal in the pot whether it is wet or dry, if the charcoal moisture is detected in dry conditions or lacks humidity then Arduino Uno will receive a message and process it to the pump so that turns on and does the watering, the message sent to aduino uno is the result of the percentage of moisture in the charcoal contained in the pot, which later this percentage will be displayed on the LCD, if the condition of the charcoal is on the threshold of humidity 49% - 60% then the pump will turn on , and if the pot is on the humidity threshold of 65% - 99% then the pump will stop.

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