

Semi automatic tobacco fertilizer design and anthropometry

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Abstract

The process of planting tobacco from the beginning of the nursery to the harvesting process is very tiring and takes a long time because it is completely done manually. In the fertilization process which is carried out by lifting the bucket, then the fertilizer solution is distributed to the roots of the plant by bending and then standing again if the availability of water has run out. If this is done continuously, then many workers complain about work risks such as back pain, arm pain, and so on. So that the tobacco fertilization process requires tools designed based on anthropometry according to the needs of workers to reduce perceived complaints. This study aims to determine the work risk, anthropometry of manual tobacco fertilizing workers, and to design a semi-automatic tobacco fertilizing device. The method used in this study is an experimental method by designing tools and testing the performance of the designed tools. Parameters observed were: level of worker complaints, worker anthropometry, dimensions and components of emitter discharge fertilization equipment and uniformity of water distribution. The results showed that the most common complaints were on body parts such as the waist, arms and shoulders, which ranged from 78% -94%. Anthropometry to design a tobacco fertilizer using the 50th percentile (P50). Measurement points such as standing height 157 cm, shoulder height standing 127 cm, waist standing 91 cm, hand length 70 cm, and hand width 10 cm. The tobacco fertilizer has components such as frames, container jerry cans, wheels, distribution hoses, panel boxes, stick sprayers. The results of testing the water discharge are by doing 4 repetitions with each discharge having 44 ml/second. The uniformity of water distribution from this tool reaches 100%.

KEYWORDS

design; anthropometry; fertilizer, tobacco

1. INTRODUCTION

Agriculture is a source of livelihood for the majority of Indonesia's population so that the agricultural sector plays an important role in economic development in Indonesia. Agriculture is

also one of the food providers for the community. Therefore, it is necessary to increase production efforts to be balanced with the rate of population growth by increasing the management of intensive farming (Wang, 2022). In the current era of agriculture requires so many innovations to do work

more effectively, especially in tobacco plants. Tobacco is a type of plant that is well known among the people of Indonesia and is spread throughout the archipelago. The tobacco plant is also a type of tropical plant that can live in a wide range of climates and is an annual plant that is classified as a plantation crop (Shahzad et al., 2021). Different from other plants, tobacco plants are used to make cigarettes.

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Based on FAOSTAT data, Indonesia's tobacco production in 2023 reached 238.8 thousand tons, an increase of 7.62% compared to the previous year, with a contribution of 4.2% to total world production. China still leads as the largest producer with a production of 2.1 million metric tons, covering 36.7% of total world production, followed by India (830 thousand metric tons, 12.5%) and Brazil (740 thousand metric tons, 11.1%) (Liang, Yang, Lou, & Ali, 2024). From an economic perspective, tobacco contributes significantly to state revenue through excise and exports. In 2023, state revenue from Tobacco Product Excise (CHT) reached IDR 213.48 trillion, with a target of increasing to IDR 230.4 trillion in 2024 (Wicaksana, Setijorini, Malau, & Saputriningsih, 2025). In 2023, the value of tobacco exports alone (excluding cigarettes and derivative products) reached around IDR 3.28 trillion. Currently, around 99.6% of national tobacco production comes from smallholder plantations, involving around 2.3 million farmer families with a planting area of around 200 thousand hectares per year (Pahari, Barman, & Talukdar, 2023). Despite its large contribution, the tobacco industry faces serious challenges in the form of price fluctuations,

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The process of planting tobacco from the beginning of the nursery to the harvesting process is quite laborious and takes a long time because it is completely done manually or using human labor. After planting, the next stage is the maintenance process. The most important maintenance in tobacco cultivation is fertilization which is done every week and is completely done manually. The fertilization process is carried out by lifting the bucket, then the fertilizer solution is distributed to the roots of the plants by bending down and then standing up again if the availability of water has run out. This process is repeated until the fertilization process is complete. If this is done continuously, then many workers complain about work risks such as back pain, arm pain, and so on. So that the tobacco fertilization process requires tools that are designed based on anthropometry according to the needs of workers to reduce perceived complaints.

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Anthropometry can be interpreted as a science that is specifically related to the measurement of the human body which is used to determine the dimensions or height of a tool. Anthropometry has an important role in the field of designing agricultural tools and machinery with the aim of creating harmony or suitability between humans and the designed tools, so that in operating the workforce they feel more comfortable, safe, and of course can reduce work risks. Anthropometric data,

which are measurements of the human body, are critical in the design of tools and tool components, such as sprayer length and wheel size, as they ensure the product is ergonomic and fits the user. By taking anthropometric data into account, designers can create tools and tool components that are not only functional but also comfortable, safe, and efficient for use by a wide range of users.

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Based on the description above, it is important to conduct research with the title "Design and Anthropometry of Semi-Automatic Tobacco Fertilizers to Reduce Occupational Risk", with the aim that workers no longer do manual fertilization but use semi-automatic fertilizers. This system can increase the efficiency and productivity of tobacco plants and help farmers minimize losses in tobacco cultivation.

2. MATERIAL AND METHODS

The method used in this study is an experimental method in which a tool design is carried out and a performance test is carried out on the designed tool. This research consists of three stages, where the first stage analyzes the level of workers' complaints on manual tobacco fertilization using the Nordic Body Map (NBM) questionnaire. Purposive location selection with certain considerations (Djoko, Yoto, Duwi, & Poppy, 2024). The second stage is to design based on the level of complaints so that anthropometric data on workers is needed. The final stage is to design and test the performance of the design results. The test parameters for the three stages refer to the performance tests of the designed tool. This research was conducted in two places, namely in the CV

workshop. Roda Tani and in Longkang Hamlet, Batu Pistil Village, Keruak District, East Lombok Regency, West Nusa Tenggara. This research was conducted from March 2023 to May 2023. Research parameters; level of worker complaints, worker anthropometry, dimensions and components of fertilizer equipment, emitter discharge, and uniformity of water distribution. The data from the research results were then analyzed using simple mathematical equations with predetermined formulas and the help of Microsoft Excel.

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3. RESULTS AND DISCUSSION

3.1 Worker Complaint Rate

In this study the first step taken was to distribute the Nordic Body Map (NBM) questionnaires to the community as many as 30 questionnaires, Each respondent was interviewed directly about what they felt in each part of their body. After conducting the interview, the second step is to process the results of the interview which part of the human body has the most complaints when carrying out the tobacco fertilization process. The following are the results of the respondents' answers to the Nordic Body Map (NBM) which are shown in [Table 1](#).

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Table 1. Percentage of Respondents in the Nordic Body Map (NBM)

No	Complaint type	Painless	Kinda sick	Sick	Very ill	Total complaints	Percentage (%)
0.	Pain in the upper neck	5	16	9	0	64	53
1.	Pain in the lower neck	5	16	9	0	64	53
2.	Pain in left shoulder	2	14	3	11	83	69
3.	Pain in the right shoulder	3	13	3	11	82	68
4.	Pain in left upper arm	4	13	5	8	77	64
5.	Pain in the back	8	9	13	0	65	54
6.	Pain in the right upper arm	4	12	6	8	78	65
7.	Pain in the waist	0	6	14	10	94	78
8.	Pain in the buttocks	12	15	3	0	51	42
9.	Pain in the ass	28	2	0	0	32	27
10.	Pain in left elbow	6	21	3	0	57	47
11.	Pain in right elbow	6	18	6	0	60	50
12.	Pain in left forearm	6	16	5	3	65	54
13.	Pain in the right forearm	9	13	5	3	62	52
14.	Pain in left wrist	2	21	4	3	68	57
15.	Pain in right wrist	3	21	3	3	66	55
16.	Pain in left hand	0	13	11	6	83	69
17.	Pain in right hand	3	21	3	3	66	55
18.	Pain in left thigh	19	8	3	0	44	37
19.	Pain in the right thigh	19	8	3	0	44	37
20.	Pain in left knee	9	8	13	0	64	53
21.	Pain in right knee	9	8	13	0	64	53
22.	Pain in left calf	7	18	5	0	58	48
23.	Pain in right calf	5	18	7	0	62	52
24.	Pain in left ankle	8	3	13	6	77	64
25.	Pain in right ankle	8	3	13	6	77	64
26.	Pain in left leg	3	16	8	3	71	59
27.	Pain in right leg	3	16	8	3	71	59

Description: Not sick with a score of 1, moderately ill with a score of 2, sick with a score of 3, and very sick with a score of 4.

Based on Table 1 the results of the percentage distribution of the Nordic Body Map (NBM) questionnaire, there are the most complaints from workers, namely on body parts such as the waist, shoulders, hands which range from 78% -94%. This needs further action because it is very posing a risk to workers.

The human capacity to lift heavy equipment is very limited and varies depending on factors such as age, gender, physical condition, and training (Adami et al., 2022). The maximum safe lifting weight for men is around 25 kg, but this can vary depending on local ergonomic guidelines. The tested equipment weighed 16 kg, if used for a long period of time it will cause complaints to the person using it. This causes complaints in the waist, shoulders, and hands. The design of work tools must be in accordance with the dimensions of the human body as a user. The sprayer size is in accordance with the dimensions of the human body and the spray button is in accordance with the standard size of the human hand, making it easier for the hand to press. The incompatibility of the design results with the dimensions of the human body will have an impact on discomfort in using the design so that it will cause premature fatigue and work stress (Karwowski & Zhang, 2021). If this goes on long enough it will lead to errors in carrying out work and an even worse impact on work accidents.

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3.2 Worker Anthropometry

After the data is processed, the results are obtained, then changes in size are made to the tool which will be designed according to the results of the interviews and the comfort of the workers. The purpose of this size change is to adjust again how comfortable the position and size of the tobacco fertilizer is according to the calculation of the percentile results of workers which will be designed for comfort in the fertilization process. The points of the human body that become anthropometric considerations for the design of tobacco fertilizing devices are body height in an upright position, shoulder height in an upright position (Hayati, Marzban, & Rahnama, 2021), waist height in an upright position, hand length and hand width. The average and calculation results of the percentile values for female workers are in [Table 2](#).

Table 2. Means and Calculation Results of Percentile Values for Female Workers

No	Anthropometry	Average (cm)	Percentil							
			P ₁	P ₅	P ₁₀	P ₂₅	P ₅₀	P ₇₅	P ₉₀	P ₉₅
1.	Standing body height	157	145	149	151	154	157	160	163	165
2.	Shoulder height stand straight	127	119	121	123	124	127	160	163	165
3.	Waist Height standing upright position	91	84	86	87	89	91	93	95	141
4.	Hand Length	70	70	66	67	68	70	71	73	74
5.	Hand width	10	10	8	9	9	10	10	11	11

Based on Table 2 above, it can be concluded that anthropometry for designing tobacco fertilizers should use the 50th percentile (P50). The 50th percentile is a moderate percentile so that in designing a tobacco fertilizing tool, female workers have no difficulty in operating the tool. The most important thing is the length of the sprayer stick, namely using a size of 70 cm according to the length of the worker's hand and the size of the hose, the longer the size, the faster the fertilization process.

3.3 Fertilizer Tool Dimensions and Components

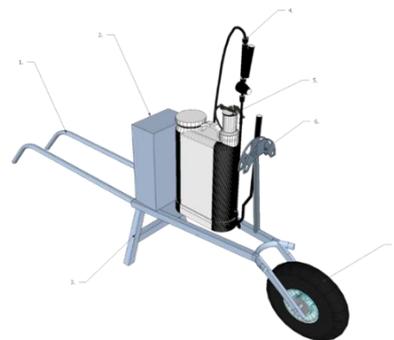
In the design process, it is essential to thoroughly understand who the end users are. A comprehensive understanding of the users' characteristics, physical capabilities, needs, and working environment is crucial to ensure that the design aligns with user expectations and operational demands. Designers must clearly identify the target users from the beginning so that the final product is not only functional but also practical, efficient, and user friendly (Tongsubanan & Kasemsam, 2025). The design of this tool cannot be separated from the interdependence of multiple design aspects. Each design element such as dimensions, weight, materials, usability, safety, and durability must be carefully considered and harmonized to create an integrated product. A successful design is achieved when all these components support each other to enhance user performance while minimizing the risk of injury and discomfort.

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One of the primary objectives of this design is to improve user comfort, which is closely linked to work efficiency and productivity. Ergonomic principles were applied throughout the design process to ensure that the tool can be used in a natural and sustainable working posture, thereby reducing physical strain and allowing users to maintain high productivity over extended periods

(Gajšek, Draghici, Boatca, Gaureanu, & Robescu, 2022). Additionally, the design process also considered the specific tasks involved in tobacco fertilization activities, ensuring that the tool is adaptable to real working conditions in the field. This includes ease of handling, maneuverability, and maintenance, which are critical for supporting daily agricultural operations. The three-dimensional (3D) model of the tobacco fertilizer applicator, which visually represents these carefully considered design elements, is presented in [Figure 1](#). The model demonstrates the overall form, functional components, and ergonomic features that are intended to maximize both comfort and effectiveness during use. The components and dimensions of the semi-automatic tobacco fertilizer as well as the specifications of this tobacco fertilizer are as follows [Table 3](#) and [Table 4](#).

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Information part of fertilizing device		
1. Holding hands	4. Stick Sprayer	7. Wheel
2. Box Panel	5. Container Jerrycan	
3. Skeleton Legs	6. Hose Roll Place	

Figure 1. 3D design of a tobacco fertilizing device

Table 3. Components and dimensions of the semi-automatic tobacco fertilizer

Tobacco fertilizer components	Dimensions (cm)	Weight (kg)
Skeleton	Wide = 74 Tall = 86 Long = 142	7
Container Jerrycan	Wide = 14 Tall = 58 Long = 38	3
Wheel	Diameter = 36	1
Hose Roll Place	Long = 1000	0,2
Stick sprayer	Long = 70	
Box panel	Wide = 12 Tall = 38 Long = 21	2,5

Table 4. Specifications for Tobacco Fertilizers

Specifications for Tobacco Fertilizers	Information
Water holding tank	Capacity 20 L
Timer	Delay relay 4 tombol DC 6-30 volt module switc control
Battery Accu (2)	12 volt 8 ampere
Dynamo (3)	Agitator, suction and dispensing, 12 volt
Stepdown	12 volt-5 volt
Hose	10 m

3.4 Water discharge

In the process of testing tobacco, it is necessary to know the water discharge discharge which aims to calculate and estimate the provision of water to a plant, one of which is the tobacco plant. So, by knowing the discharge of water flowing in the process of channeling water to plants, it can be used more effectively and efficiently in the fertilization process. The results of measuring water discharge in tobacco plants can be seen in the following [Table 5](#).

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Table 5. Results of water discharge measurements on tobacco plants

Water Volume (ml)	Time (sec)	Discharge (ml/sec)
220	5	44
440	10	44
440	10	44
440	10	44

The process of measuring the water discharge was carried out with 4 repetitions with the distance of the tobacco plants from one plant to another, namely 50 cm. In the first repetition with the first fertilizer dose on tobacco plants as much as 220 ml of water on one plant with a time of 5 seconds on 1 tobacco plant, the second repetition with the second, third and fourth fertilizer doses on tobacco plants as

much as 440 ml which takes 10 seconds. from the test results it can be concluded that the more volume of water needed, the more time for water distribution will be. One of the efforts made to increase tobacco productivity is by fertilizing. Fertilization is a plant maintenance activity that aims to improve soil fertility by providing nutrients in the soil needed by plants (Barlóg, Grzebisz, & Łukowiak, 2022). The important thing in fertilization that needs attention is the efficiency of fertilization. In order for fertilization to be effective and efficient, the type of fertilizer must be adapted to the conditions of the land and plants, and to make optimal use of natural resources.

3.5 Uniformity of Water Distribution

The last stage is the process of measuring the distribution of water in each tobacco plant, this process is carried out in order to find out whether the distribution of water from the tool to the tobacco plants is running smoothly. In the test results of the tobacco fertilizing tool, it was found that the larger the diameter of the distribution hose, the faster the distribution of water to the tobacco plants. The time to fill the water into the storage jerry can takes 8 minutes and the time to use this tool is 8 hours if the power of the tool is full, for the dosage of self-fertilizer in a 20 liter storage jerry can, it is measured using a 220 ml glass of urea fertilizer at the first fertilization, 440 ml urea fertilizer along with a mixture of NPK and other fertilizers in the second fertilization and so on (Table 6).

Table 6. Results of uniformity of water distribution in fertilizing tobacco plants.

Water Volume (ml)	Time (sec)	Debit (ml/sec)	Cu (%)
220	5	44	100
440	10	44	
440	10	44	
440	10	44	

Based on the table above, it is explained that the results of the uniform distribution of water are said

to be uniform because it achieves a yield of 100%, although this tool still has many shortcomings such as there is no place to dispose of the remaining dregs from fertilizer, the place for setting the time for distributing water is quite difficult so farmers must study hard first. before you can operate it yourself. The advantages are that the risk to workers is reduced because the tool is operated in a standing state thereby reducing the risk of pain in the waist or others due to bending down, the power of the tool is relatively long because it can be used within a day, the discharge of water from the stick sprayer is not too hard so the soil can absorb water properly and the soil around the tobacco plants does not scatter (Ojha, Gautam, Jebelli, & Akanmu, 2024). The current trend of farmers is to use chemical (inorganic) fertilizers for practical reasons. Even though the use of inorganic fertilizers has several weaknesses, namely the use of excessive doses can cause environmental pollution, especially if its use continuously for a long time will cause land productivity to decrease. An alternative effort to improve the physical properties of the soil or increase the fertility of agricultural soil in a sustainable manner is by adding organic matter (Maticic, Dugan, & Bogunovic, 2024).

4. CONCLUSION

Based on the results of the analysis limited to research, it can be concluded that; Occupational risks in the manual tobacco fertilization process are such as back pain, arm pain and so on. So that it poses a serious work risk to tobacco farmers. Anthropometry for designing tobacco fertilizers should use the 50th percentile (P50). With measurement points such as standing height 157, shoulder height standing 127, waist height standing 91, hand length 70, and hand width 70. The tobacco fertilizer has components such as frame, container jerry can, wheels, hose distributor, panel box, stick sprayer. The results of testing the water discharge by doing 4 repetitions with each discharge having 44 ml/second. The uniformity of water distribution from this tool reaches 100%.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Budy Wiryono: Writing – original draft, Conceptualization. Muanah: Conceptualization, Supervision. Noviani Asriani: Methodology, Conceptualization, Writing – review & editing.

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CONFLICT OF INTEREST

The authors declare no conflict of interest

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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