*TEKNOTAN, Vol. 17, No. 2, Agustus 2023*
*ISSN 1978-1067 (Print), ISSN 2528-6285 (Online)*
*DOI 10.24198/jt.vol17n2.3*

# Design and Build of a Multifunctional Portable Fertilizer

***Rancang Bangun Alat Pemupuk Portabel Multifungsi***

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Diterima: 31 Maret 2023; Disetujui: 6 Juni 2023

**ABSTRACT**

Pangestu Farmer Group is a farming group in Pandanrejo Village, Batu Regency, that has high-quality sweet corn as a strategic asset with often fluctuating yields. Consequently, the market demand cannot be met. The main problem of fluctuations in corn yields is due to improper fertilization methods. Applying liquid fertilizer during the rainy season can result in nutrients being washed away by rainwater, but when granular fertilization is used, this results in increased costs and labour. A solution is needed to solve this problem so that the fertilization process is correct, and the timing of fertilization and labour costs can be reduced. Therefore, a portable fertilizing technology based on spring valves is needed. The goal is to develop and manufacture a valve spring-based portable fertilizer that can increase the effectiveness and efficiency of the fertilization process. The comparison of type 1 and type 2 fertilizers lies in the raw material used. Commercially available hand sprayer for comparison in design. Ergonomic analyses are also considered in the design of the fertilizer, both in terms of user safety and comfort. The method in this study is to design tools with power and ergonomic calculations, manufacture tools at Sahabat Teknik Workshop, and conduct tests at Brawijaya University's Agricultural Power and Machinery Laboratory. The test results for portable fertilizer types 1 and 2 show great advantages, namely, increase in working capacity 20 times to 1.2 ha/hour, reduce the number of workers from 7 people/ha to 5 people/ha, reduce operating time, reduce labour costs and increase farmers' income by up to 57, 72%/year.

**Keywords:** Design; portable fertilizer; Batu regency; farmer

***ABSTRAK***

*Kelompok Tani Pangestu merupakan salah satu kelompok tani di Desa Pandanrejo, Kabupaten Batu, yang memiliki jagung manis berkualitas tinggi sebagai komoditas strategis dengan hasil panen yang sering berfluktuasi. Akibatnya, permintaan pasar tidak dapat dipenuhi. Masalah utama fluktuasi hasil panen jagung adalah karena metode pemupukan yang tidak tepat. Pemberian pupuk cair pada musim hujan dapat menyebabkan nutrisi terhanyut oleh air hujan tetapi jika dilakukan pemupukan granular maka akan menimbulkan biaya dan tenaga kerja yang lebih tinggi.Perlu adanya solusi dalam menyelesaikan permasalahan tersebut, agar proses pemupukan tepat dan waktu pemupukan, biaya tenaga kerja dapat ditekan. Oleh karena itu, diperlukan teknologi pemupukan portable berbasis spring valve. Tujuan dari perancangan dan pembuatan alat pemupuk portable berbasis pegas katup yang dapat meningkatkan efektifitas dan efisiensi proses pemupukan. Perbandingan alat pemupuk tipe 1 dan tipe 2 terletak pada material dasar yang digunaka. Hand sprayer komersial sebagai pembanding dalam perancangan. Analisis ergonomis juga dipertimbangkan dalam merancang perangkat alat pemupuk baik dari segi keamanan dan kenyamanan pengguna. Metode pada penelitian ini yaitu perancangan alat dengan perhitungan gaya dan ergonomis, pembuatan alat di Bengkel Sahabat Teknik, pengujian dilakukan di laboratorium Daya dan Mesin Pertanian Universitas Brawijaya. Hasil pengujian alat pemupuk portable tipe 1 dan 2 menunjukkan manfaat yang besar, yaitu; peningkatan kapasitas kerja 20 kali lipat menjadi 1,2 ha/jam, penurunan jumlah tenaga kerja dari 7 orang/ha menjadi 5 orang/ha, pengurangan waktu operasi, pengurangan biaya tenaga kerja, dan peningkatan pendapatan petani hingga 57,72%/tahun.*

***Kata kunci:*** *Desain; pemupuk portabel; kabupaten batu; petani*

## INTRODUCTION

The fertilization issue is one of the things that farmers often experience. Improper fertilization methods and climatic conditions can cause crop yields to fluctuate, as experienced by sweet corn farmers in Pandanrejo village, Kota Batu, East Java (Kota Batu Government Service, 2012). So far, the fertilizer given is only in the form of liquid fertilizer where in the rainy season, the nutrients are likely to be lost along with the flow of rainwater, whereas if granule fertilizers are applied, the labor costs will be high. According to Pangaribuan (2012) and Rhivaraja and Parameswaramuthy (2014), the use of tools in the form of a hand sprayer could make the fertilization process lighter and faster. However, empirically liquid fertilizers are only suitable to be applied in the dry season where the soil is dry (Lingga, 2003).

Ergonomic factors also need to be considered when designing a device (Mufidah et al., 2021). The basic philosophy of ergonomics is to create a design that provides the user comfort, safety, and physical health (Dawal et al., 2015). Moreover, according to Van Niekerk et al (2013), a job or work process that requires a body balance, if there is a disturbance during the work process, it will be able to reduce the muscle's ability to control the load. Based on Mehta and Tewari (2000), the operator bears the burden of applying technology using agricultural tools and machinery. The design concept based on ergonomics or human factors in engineering design needs to consider the operator's body posture with the design of a tool or machine to do work, therefore repetitive work processes carried out over a long period can provide comfort, safety, and physical health of the operator.

Implementation of portable fertilizer tools is one of the innovative solutions that are offered. This portable tool can be used as a liquid or granule fertilizer applicator by utilizing a spring valve to set fertilizer output. Furthermore, by using this technology the release of fertilizers can be regulated, economical, ergonomic, easy to manufacture, and easy to use. The valve spring is attached to the end of the applicator rod. The working principle of this technology is if the trigger of the applicator rod is pulled, the spring will stretch and cause the valve to open, thus the fertilizer can come out due to the earth's gravitational force. Then if the trigger is released, the spring will return to normal and cause the valve to close, and the fertilizer stops coming out.

This paper aims to design and manufacture a valve spring-based portable fertilizer that can increase the effectiveness and efficiency of the fertilization process. A comparison of type 1 and type 2 *Design and Manufacture of Portable and Multipurpose Fertilizer devices*, as well as commercial hand sprays is also discussed in this paper. An ergonomic analysis is also considered in designing this device.

## METHODS

### Location

The Pangestu Farmers Group is a farmer group in Pandanrejo Village, Batu Regency. also, Power and Machinery Laboratory, University of Brawijaya Malang. The research stages are divided into two, namely the initial survey stage, Design and Testing. Site surveys are used to find out initial problems at partner locations. Designing Stages includes a study of literature on the design of existing fertilizers, then modifications are made. and Study literature is used to provide basic references to support research. Testing stages include data collection, data processing and analysis, ergonomic aspects of tool design and conclusions.

### Design and Consideration

Most of the fertilizers in Indonesia are fertilizer tractors with an effective machine field capacity of 0.137 ha/hour (Sagitta, 2018). However, this fertilizer tractor can only be used on sloping land and the price is relatively expensive. In addition, there are semi-automatic fertilizers with diesel power that can be applied on sloping or bumpy land but only for liquid fertilizers, then there are similar fertilizers that use human power which can be applied on sloping or bumpy land but only for liquid fertilizers as well. The fertilizer proposed is designed with the legal principle of Galileo Galilei where all objects that have mass will fall due to the Earth's gravity. The working mechanism of the applicator rod uses a spring system to open and close the valve. The design proposed here is suitable for both granule and liquid fertilizer coverage. The proposed design also considers the operator's workload so that the highest productivity can be obtained with the lowest possible energy.

### Overall Design

The design of this portable and versatile fertilizer device based on valve springs was developed in a three-dimensional model with AutoCAD 2013. This device is designed to be operated by one person as shown in Figure 1. This fertilizer device comprises a frame, tank, back cushion, connecting hose, valve, lever, applicator rod and shoulder strap. There are 2 types of tanks: type 1 made of stainless steel (Figure 1a) and type 2 made from used mineral water gallons (Figure 1b). While the applicator rod is designed to resemble a firearm. Either Liquid fertilizer or granule fertilizer can be applied using this tool by replacing the applicator rod.

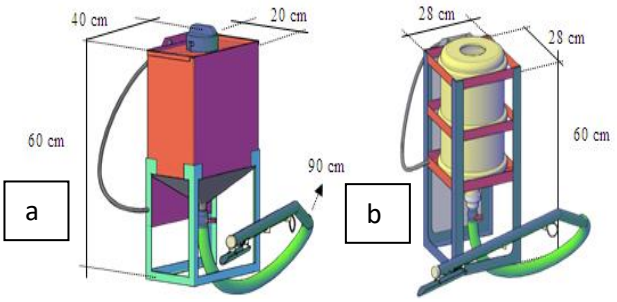


Figure 1. Design of Fertilizer Device (a) Type 1 and (b) Type 2

### Functional Design

The portable fertilizer machine functions to ration fertilizer uniformly with a capacity of 15 L. In its application, this fertilizer is designed portable to use both liquid fertilizer and granule fertilizer by replacing the road applicator. Fertilizers are also designed to adjust the fertiliser dose uniformly as needed. The function of each machine part can be seen in Table 1.

### Calculation of Spring Constants

One thing that needs to be considered in designing this fertilizer is the value of the spring constant (k) on the valve spring. It is a measure of the spring's stiffness. According to Aditya A. and Suprijadi (2012), the force (F) that can be applied is proportional to the k and the change in length (Δx) can be formulated as follows:

Table 1. The function of each fertilizer device part

| The main function | Subfunctions | Components/Mechanisms |
|---|---|---|
| The ration of fertilizer for liquid fertilizer and granule fertilizer evenly and uniformly | Support the fertilizer unit | The frame design is from 304 stainless steel plate |
| | Holds liquid fertilizer or granules | Hopper/tank is made of stainless steel or gallons |
| | Regulate fertilizer output | The application road is made of PVC 3/4 dim pipe |

$$F = -k \Delta x \quad (1)$$

Where:
F : Force (N)
k : Spring constant (N/m)
Δx : Change in spring length (m)

The negative (-) indicates the direction of the spring force opposite the pull force. If only see the magnitude of the spring force without paying attention to the cause, can find out the value of k or the spring constant, which can be calculated using the following formula:

$$F = k \Delta x \quad (2)$$

$$w = mg \quad (3)$$

Where:
w : Weight (N)
m : Mass of valve (kg)
g : Gravity (m/s$^2$)

If the value of F is equal to w, which is the load imposed on the spring and the value of Δx is the difference in the increase in the length of the spring obtained from the results of the stress experiment with a certain load with three repetitions, then the value of k can be calculated using Equation 1 and Equation 2.

## RESULTS AND DISCUSSION

### The Design of Fertilizer Devices

Two types of fertilizers are produced as shown in Figure 2, namely fertilizers with metal tanks (Figure 2a) and fertilizers with tanking gallons of used mineral water. Each fertilizer tank has a capacity of 15L. The applicator rods are designed with 2 different types to apply to liquid fertilizer or liquid pupils. This tool is also equipped with a back cushion or sponge, making operating more comfortable. Moreover, this tool has good portability, meaning it can be taken anywhere and is easy to apply even though the land is wavy and steep.

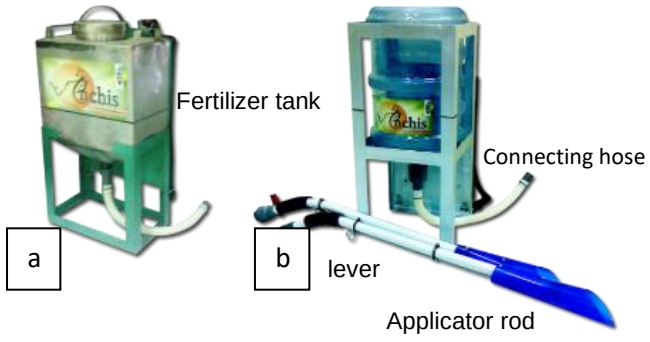


Figure 2. The Design of Fertilizer Devices (a) Type 1 and (b) Type 2

The fertilizer tank functions as a reservoir for liquid or granular fertilizer, the applicator rod functions as a nozzle to direct the fertilizer to fall to the right target when applying fertilizer to plants and the connecting hose function as a link between the tank and fertilizer.

### Work Principle

If the lever is pulled, the main valve will open. So that the granule / liquid fertilizer will come out. If the lever is released, the main valve will close again. It can be simulated in detail in the following Figure 3.

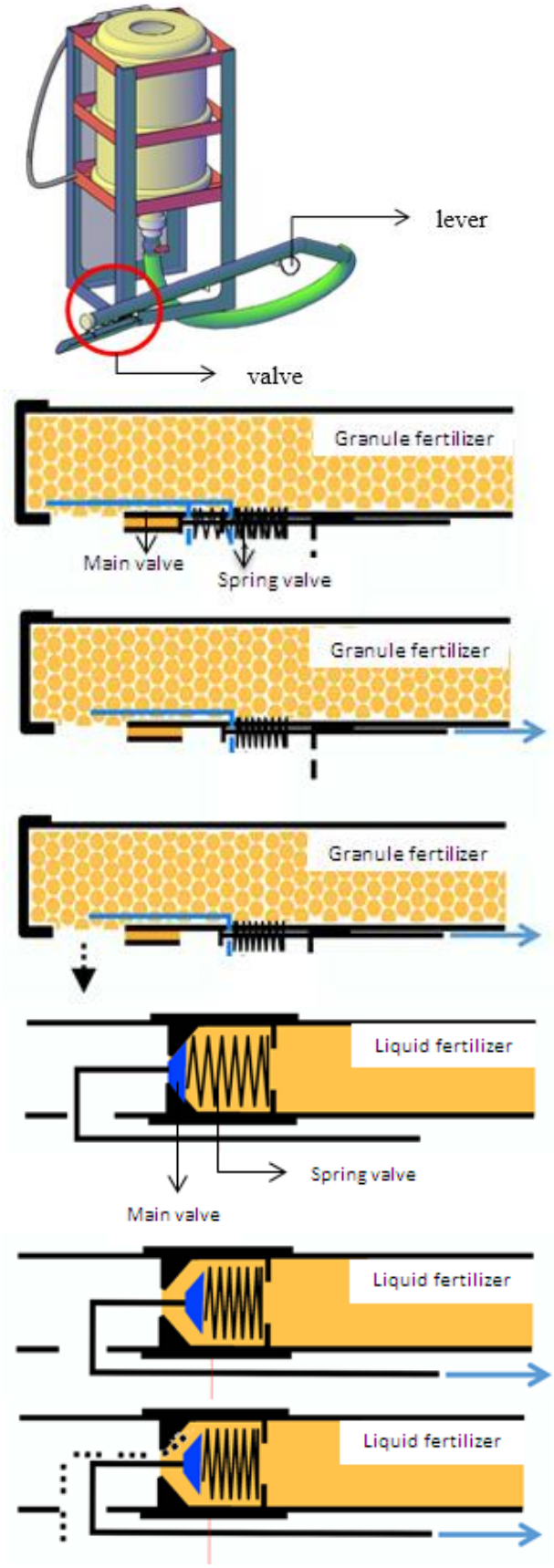


Figure 3. Work principles of a portable fertilizer device

Tabel 1 . Experiment result data

| Parameter | Value | Unit |
|---|---|---|
| Mass (m) | 1,226 | kg |
| Gravitational Acceleration (g) | 9,81 | $m/s^2$ |
| Weight (w) = m x g | 12.027 | N |
| Final Spring Length ($x_t$) | 1,43 x $10^{-2}$ | m |
| Initial Spring Length ($x_0$) | 2,50 x $10^{-2}$ | m |
| Difference in Length ($\Delta x$) = $x_t$- $x_0$ | 1,07 x $10^{-2}$ | m |
| Spring Constant (k) = F/$\Delta x$ | 1.124,02 | N/m |

Table 2. Comparison of type 1 and type 2 portable fertilizer devices and commercial hand sprayers

| No | Parameter | Type 1 | Type 2 | Commercial Hand Sprayer (Swan) |
|---|---|---|---|---|
| 1 | Tank | | | |
| | Length (cm) | 40 | 28 | 32* |
| | Width (cm) | 20 | 28 | 18* |
| | Height (cm) | 60 | 60 | 48.5* |
| | Max. capacity (L) | 15 | 15 | 14** |
| 2 | Applicator Rod | | | |
| | Length (cm) | 90 | 90 | 100* |
| | Diameter (cm) | 2.6 | 2.6 | 1.8* |
| | Handle (cm) | 3 | 3 | |
| | Spring Constant k (N/m) | 1,124.02 | 1,124.02 | - |
| 3 | Mass (Kg) | 8 | 4.8 | 5.4* |

Sources: * Agriculture Technology Research Institut (2007)
** Nurlinah (2015)

Table 3. Comparison of fertilization results; after and before using portable fertilizers

| Parameters | Traditional method | With a portable fertilizer device | Increasing/decreasing towards manual method (%) |
|---|---|---|---|
| Effective Capacity (ha/hour) | 0.0125* | 0,2* | +18,75* |
| Number of Workers (person/ha) | 7 | 5 | -28 |
| Cost of Workers (IDR /ha /day) | 245.000 | 175.000 | -28 |
| Fertilizer needs (ton/ha) | 3 | 2 | -33 |
| Increase in farmer income (IDR/ha/ year) | 36.480.000 | 58.800.000 | +57,72 |

Information: * = Test results

**Calculations and Technical Specifications**

**Results of Spring Constant Calculation**

The calculation of the spring constant is based on equation 1, the results of which can be seen in Table 1. Based on obtained data above, these could be used to figure out the spring constant (k) by using equation 1, therefore the obtained spring constant is 1.124,02 N/m. The value was approximately five times higher than the spring constant of the ballpoint that is 221 N/m and it was much smaller than the value of the spring constant of a car suspension, which is $10^5$ N/m (Sears dan Zemansky, 2002).

**The Force Required to Open the Discharge Valve**

The force required to open the valve (F) was calculated based on the results of the spring constant (k) of 1,124.02 N/m, and the desired distance of $\Delta x$ was 1.06 cm or 0.0106 m therefore, by using Equation 2 the force required to open the valve (F) was 12 N. This force could be assumed to be equivalent to carrying a load of 1.2 kg with 1 finger, thus the load feels light and ergonomic. From these calculations' technical specifications of this fertilizer device can be seen in Table 2.

**Ergonomic Analysis**

According to Harrington and Gill (2005), ergonomics is an important aspect of a tool design that aims to balance machine tools with workers, thus workers do not need to adjust the tools or machines used. The basic philosophy of ergonomics is to create a design that provides comfort, safety and physical health for the user (Dawal et al., 2015), furthermore according to Van Niekerk et al., (2013), a job or work process that requires body balance if there is a disturbance during the work process will be able to reduce the ability of the muscles to control the load.

Ergonomic value is affected by three aspects, namely aspects of humans, machine tools and the environment. Grimmer et al. (2012) and Mufidah et al. (2021) stated that in order not to interfere with health, the allowable load mass is not more than 15% of body mass. Therefore, the recommended fertilizer capacity for this portable fertilizer is 9 L, the average mass of adults in Indonesia is 60 kg (Syuaib,

2015). And the value of the spring in this tool is 1,124.02 N/m. F or the force required to open the valve is 12 N. Force required to open the valve is equivalent to carrying a load of 1.2 kg using only 1 finger and it feels very comfortable.

Generally, the design of a Portable Fertilizer Device is equipped with a frame, tank, back cushion, connecting hose, valve, lever, applicator rod and shoulder strap. The back cushion is made of a sponge, so users are comfortable using it. Handle on application road equipped with pads that adjust the shape of the hand, The diameter is 3 cm according to anthropometric data grip diameter (inside) farmer Indonesia is 3.1 cm, 3.7 cm, 4.4 cm for 5, 50 and 95 percentiles respectively (Syuaib, 2015). The shoulder strap can be adjusted according to the size of the farmer's back so that it is comfortable to use. The spring valve is opened by direct pulling, touching, or levering. Those lead to significant consciences in calculations not just assumption F=W). A load of 1,2 kg is uncomfortable if you pull by one finger.

**Increasing the Effectiveness and Efficiency of Fertilization**

This portable fertilizer was applied on a corn area of 0.2 ha, indicating a fertilization capacity 20 times higher than manual fertilization, so the effectiveness and work efficiency can be increased, as seen in Table 3. It can be explained from Table 3 that the ratio of adequate capacity can be increased up to 18.75%. It can also reduce the amount of work required, operating time, and labor costs. Fertilizer needs can decrease by up to 33%, if compared to the manual way. So this device's overall income can be increased up to 57.72% / year.

For further research, this portable fertilizer technology will be equipped with an Arduino-based system and artificial intelligence to help farmers control and provide information automatically about the amount of liquid fertilizer when the fertilizer runs out at LCD.(Sabar et al., 2019b, 2019a; Sabar, Hariyanto, et al., 2021; Sabar, Wijaya, et al., 2021)

## CONCLUSION

This portable fertilizer device of a frame, tank, back cushion, connecting hose, valve, lever, applicator rod, and shoulder strap. There are 2 types of tanks: type 1 made of stainless steel and type 2 made from used mineral water gallon. The tank has a maximum capacity of 15 L and has two applicator rods for liquid fertilizer and granules. The shoulder strap can be adjusted, and the back cushion is made of a sponge so that users are comfortable using it. The test results for portable fertilizer types 1 and 2 show great advantages, namely; Increase in working capacity 20 times to 1.2 ha/hour, reduce the number of workers from 7 people/ha to 5 people/ha, reduce operating time, reduce labor costs and increase farmers' income by up to 57.72%/year.

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