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1 - 1 of 1 Items

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Development of Mechanical Organic Fertilizer Machine: Simulation, Implementation, and Performance Test

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***Abstract*— The objective of this research was to develop technology mechanical fertilizer machine was designed in order to optimize the harvest to be achieved by using SRI. The target to be achieved is from the results of this study will be expected to support the acceleration of increasing the level of farmers economy, especially because the achieved production can be more optimal. On the other hand, the cost to be paid for fertilization wages can be suppressed. The ability of a mechanical fertilizer machine to be able to replace the use of labor during each growing season will save the cost of production so it will be able to improve the welfare of farmers. To design the machine, mathematical model and simulation were developed. The performance test showed that this machine generates noise level 94.48 dB. Engine specifications; Length 240 cm, width 124 cm, height 110 cm and number of fertilization path is 4. From economic analysis is obtained that Basic cost = Rp. 184.990,88 / ha; BEP = 72,7 ha/year; B / C ratio = 1.34 and NVP =7.139.779. While the effective capacity 90,137 hectares per hour; Power of motor used was 7 HP and durability of the operator is 4 hours. Hopefully, this research can support the target of achieving an average production of 10 tons/ha can be realized so that Indonesia really achieves self-sufficiency in rice.**

***Keywords*—fertilizer machine, fertilization and mechanical organic fertilizer.**

I. INTRODUCTION

The increase of rice production from 4.75 ton/ha (BPS, 2003) to 7.0 ton/ha in order to eliminate rice import can be achieved because rice production potential can reach 10 ton/ha. Nowadays, the system of Rice Intensification (SRI) cultivation that has been tried in several places in Indonesia shows higher productivity. In some districts in West Sumatra applying SRI reached an average yield of 7.8 tons / ha (Kasim, 2004). Meanwhile, the results of SRI implementation in some places in West Java showed the achievement of 8.5 tons / ha (Irrigation Center, 2006). But all the results of this trial has not been so successful when applied directly to the rice fields of the community or farmers.

The problem is with the technology applied the productivity of paddy field is still very low. The application of cultivation technology such as superior varieties, fertilization, plant balance, harvest and post-harvest which is accompanied by the advantages of counseling and production has not provided optimal results. The superior level of productivity is still far below the production potential of 10 tons per hectare.

The national rice production growth rate is not enough to keep pace with domestic demand. All of these things need to be updated. Application of SRI Method (Paddy Intensification System) indeed gives a better result than not yet optimal. In the first phase of the research, efforts were made to overcome the problem of weeding weeds in rice paddy area with SRI system by creating mechanical handling machine. The next stage that needs to be done is by providing fertilizer in rice plants with a precise, efficient and appropriate dosage in order to obtain optimal production results.

The success of SRI is the planting of one seed of perforation and is done at the age of seed 7 - 10 days and the distance of planting, the number of productive tillers of paddy rice can reach 60 stems per clump. Plant density and density in rice fields is very high. This condition makes manual fertilization ineffective and uneven. Because it can not be spread evenly per clump, many of these fertilizers are not reach down to the ground like because it will be stuck on leaf midrib, will waste because of evaporation.

Field observation results found in the conventional rice cultivated area and planted with SRI system, the fertilization process is done manually by hand, uneven spread of fertilizer, consequently the growth of rice plants is not the same. So at the time of harvest, the maturity of the grain is not the same or uneven pine-grain, consequently, the harvested results are not optimal because many grains of rice are not pithy earlier.

In the rice field area SRI system is more difficult to do fertilization because the density of plants and soil conditions denser so that increase more labor to spread fertilizer and it is not effective because it is not given near the base of the plant. So SRI has not been optimal without being supported by proper and effective fertilization process in plants.

On the other hand, the depreciation of farm labor continues to occur and tend to increase. While at the same time required a large enough amount of manpower to perform proper and correct fertilization. As a result wages for fertilization to be larger. The base of this problem, the fertilization process should be done with appropriate time, accurate dosage per plant and proper way in order to achieve optimal production.

To overcome this problem, mechanical fertilizer machine was designed in order to optimize the harvest to be achieved by using SRI method above. Hopefully the target of achieving an average production of 10 tons/ha can be realized so that Indonesia really achieves self-sufficiency in rice.

II. Formulation of the Problem

Application of SRI system rice pattern (the System of Rice Intensification) provides many advantages compared with traditional cropping pattern. However, the growth of saplings in the rice field area is very fast, in one clump of rice can reach 60 productive saplings. A large number of productive tillers accompanied by the canopy of the plantation in the rice fields will close the surface of rice fields. So need to be given more fertilization than usual. Provision of fertilizer in this rice field must be appropriate dosage and spacing for proper targeting of fertilizer at the base of the plant. Rice fields are quite dense by the canopy of the plant resulting in fertilizer given to the plant manually not effectively accepted by the plant. In addition, the limited number of manpower to fertilize the field, while the availability of labor in agriculture is limited. So, for fertilization cost big for labor wage. Based on this problem, there should be a way out to overcome the problem of crop fertilization in the rice field either using SRI system or conventional.

The purpose of this research is to create a prototype of organic fertilizer spreader machine for paddy rice and also can be used for other horticultural plants, can be arranged spacing and dose of fertilizer, multi-function, efficient, high capacity in accordance with the needs of farmers so that fertilizer can be given to place and proper dose on the plant. Also, can overcome the problem of labor limitations to fertilize. In addition, it helps to alleviate the work and farmers' operational costs so that the fertilization process is not a problem for farmers.

The target to be achieved is from the results of this study will be expected to support the acceleration of increasing the level of farmers economy, especially because the achieved production can be more optimal. On the other hand, the cost to be paid for fertilization wages can be suppressed. The ability of a mechanical fertilizer machine to be able to replace the use of labor during each growing season will save the cost of production so it will be able to improve the welfare of farmers.

Besides, it is hoped that the creation of a prototype of this machine will encourage the growth of workshops of agricultural machinery which will produce appliance and agricultural machinery applied so that it will open new job field in Lima Puluh Kota and West Sumatera generally.

In addition to the above, other advantages of this machine are the machine has the potential to be multi-function equipment that can be modified and/or upgraded to other types of machines by adding other implementations on the machine.

Further, this machine can be converted into planting tools, fertilizer tool and also the harvesting tool by replacing or adding components of the tool above on this machine. It could even be some tool components mounted on this machine so that one machine can do several jobs at once such as adding a fertilizer tool on the machine so that the engine does the fertilization in each operation.

This research will also encourage the workshop of Political Affairs Payakumbuh become the workshop of engineering tools and agricultural machinery especially tools and agricultural machinery

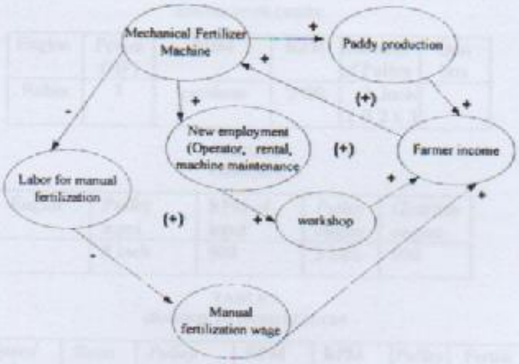

Figure 1. Mechanical Causal Diagram of mechanical loop.

III. Program Simulation

In general, the simulation is defined as imitating a system or activity without having to display it in real terms. The simulation technique becomes an option when other means of analysis are impossible or not performed. Various combinations and alternatives can be learned through simulations prior to their implementation in the field. This will reduce the occurrence of errors that result in enormous costs in its implementation.

Simulation is an activity that enables the reviewer to draw conclusions about the behavior of a system, through the study of a harmonized behavior model, the causal relationship being similar to or as it is in the actual system.

According to Kakiay (2004), the simulation can be interpreted as a system used to solve real-life problems filled with uncertainty by using a particular model or method and more emphasis on the use of computers to get the solution.

Some of the advantages that can be obtained by simulating the simulation are: (a) saving time, (b) being able to monitor varied sources, (c) correcting calculation errors, (d) can be stopped and re-run, and (e) easy reproduced.

IV. METHOD

The research process begins with identifying problems that exist in the SRI system. Next determine the design criteria ie; the design should be simple but efficient, high capacity, using locally available materials as well as the expected multi-purpose machine that implemen could be replaced by other implemen (fertilizer, harvesters).

The next stage is to draft the concept by taking into account the necessary functions and structures of the machine. After this test the engine performance and evaluation of whether the machine in accordance with the required. If yes can be followed by the stage of applying the machine to the community. The flow chart of this stage can be seen in Figure 2.

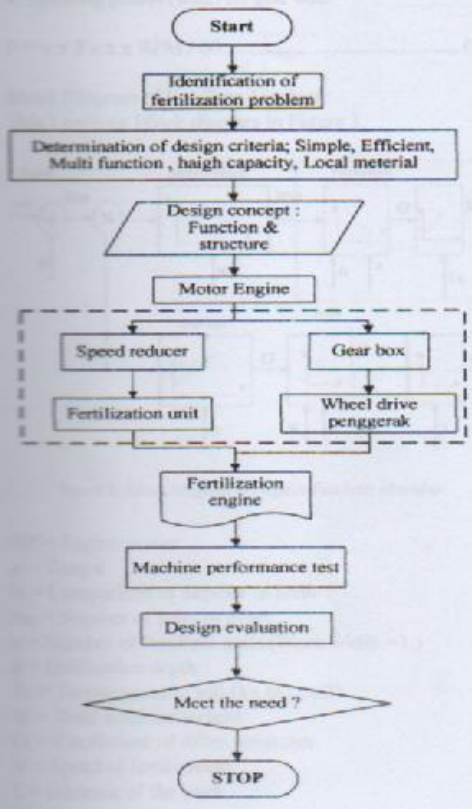

Figure 2. Flow Chart of Research Phase Engineering of Fertilizer Machine

Mathematical Model of Fertilizer Machine

Mathematically, the ability that can be achieved by this mechanical fertilizer machine is a function of engine power, RPM, work width, work speed and weed density in the field. The capacity of the machine to fertilize can be calculated in the following ways:

$\pi 1 = f(\pi 2)$ ....(1)

$\pi 1 = KKe / (Wt \times V)$..(2)

$\pi 2$ = area covered by weed (m2) / total path area of fertilization (m2)......(3)

The relationship between machine work capacity and weed density, mathematically can be seen as follows:

Mathematical models that work on each component of the fertilization machine are as follows:

1. Power to drive the wheels of the fertilizer machine
$P = Cr \times W \times V / 75$ .... (4)

2. Fertilizing power of machine:

$P = Ts \times d \times L \times RPM \times 2\pi / (75 \times 60)$ .... (5)

3. RPM (rev / min) on the speed reducer:

$RPM1 = N1 / N2 \times RPM\ 2$ .... (6)

TABLE 1
ENGINE TO GEARBOX

Engine	Power (HP)	BBM	RPM	Diameter of Pulley	Gear box
Robin	7	gasolene	2400	3 inch (B 2 x 3	

TABLE 2
GEAR BOX

Engine	*Pulley* input	RPM of input	*Pulley output*	*Gearbox output*
	8 inch	900	3 inch	900

TABLE 3
GEARBOX TO SPEED REDUCER

Speed Reducer (type)	*Ratio*	*Pulley* input	RPM input	RPM out put	*Pulley* output	Fertilizer unit
P A	1 : 20	5 inch (B 2x5)	540	27	6 inch	

TABLE 4
SPEED REDUCER TO UOTPUT OF FERTILIZER

Speed reducer	RPM out put	*Puley out put*	Pulley input	Rpm of fertilizer
	27	6 inch	3 inch	54

Engine transmission to wheel drive

1. The radius (R) of the wheels is desired = 50 cm
   The circumference of the wheel circle = π D = 314 cm
2. The desired linear velocity is 5 km / h (walking speed) = 5000m / 60 minutes = 83 m / min
3. Rpm required wheel = 83 m / 3.14 m x Rpm / min = 26.43
   Rpm wheel = 26 rpm / min
4. 4. Transmission gearbox with composition gear M3 x 18 and M3 x 44
   Ratio rpm = 18/44 x 18/44 x 18/44 x 18/44 = 0.028 = 0.03
   or 3: 100
5. Rpm top shaft = 100/3 x 26 = 866,67 rpm ≈ 900 rpm
6. Pulley gearbox = (Rpm engine / Rpm shaft) x pulley engine
   = (2400/900) x 3 inches = 7.9 inches ≈ 8 inches

4. Spinning power (watt) on gear box:

$$P = \sigma \times 2 \times \pi \times RPM / 60 \quad \text{.......... (7)}$$

Block Diagram of Fertilizer Machine
This Fertilizer Block diagram in Figure 3.

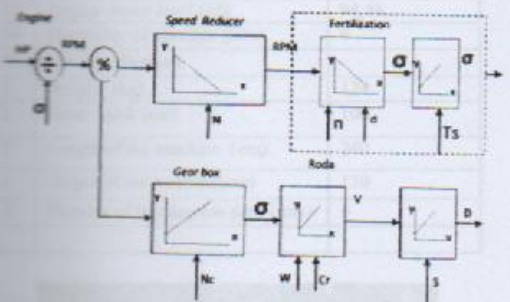

Figure 3. Block Diagram of Organic Fertilizer Machine

HP = Engine power
σ = Torque
N = Comparison of number of teeth
Nc = Number of pairs of gears
n = Number of fertilizer units (Work width = L)
d = fertilization depth
Ts = Torque specific soil (kg.m / cm2)
W = Total machine weight
Cr = Coefficient of roller resistance
V = Speed of fertilization
S = Distance of the track
D = Wheel diameter

Data analysis
The parameters observed in this study are:
1. Effective capacity of tools
The effective capacity of fertilization can be by comparing the area of fertilized land with the time required for the fertilization.

$$K\,ef = A / T \quad \text{.......... (8)}$$

2. Theoretical Capacity
The theoretical capacity is obtained by multiplying the width of the work by the speed of the machine

$$K\,Te = W \times V \times 0.36 \quad \text{.......... (9)}$$

Working speed (V) can be calculated by the formula:

$$V = S / t \quad \text{.......... (10)}$$

3. Field Efficiency
Field efficiency can be calculated by comparing the machine's effective capacity with its theoretical capacity with the following equation:

$$Eff = K\,eff / TK\,Te \times 100\% \quad \text{.......... (11)}$$

V. Economic Analysis of Fertilizer Machine

A. Page Layout

The economical analysis of the machine can be calculated using fixed variable cost, fixed cost and number of working hours per year and the effective working capacity of the machine, so that we can calculate the cost of fertilization by machine using the equation:

$$BP = (BT / T + BTT) / K\,ef \quad \text{.......... (12)}$$

4. b Break-Even Point (Break Event Point- BEP)
BEP aims to know the minimum production volume so that the income will cover the total cost of production. BEP can be calculated using the equation:

$$BEP = BT / (h1 \times BP) - (BTT / KP) \quad \text{.......... (13)}$$

5. Power Operator
The power of the operator is measured by heart rate, the operator's heart rate is measured before performing the operation and shortly after performing the machine operation in the field.

6. Used Motor Power
The power used in the operation of this fertilizer machine can be found using the formula:

Mechanical Power = Chemical power x ∂ gasoline......(14)
Fuel used x p gasoline x Heat value of gasoline x 4.2. (15)
Chemical Power = 3600 x 735..........................(16)

7. Engine Noise Level

To know the level of noise, the noise level is measured by sound detector that is sound level meter. The data is then matched to a standard of noise that is still safe for humans and performs comparisons with research conducted by experts who take into account the noise level of the device with the length of operation of the device.

Machine Performance Observation Results.

Based on the result of observation data of fertilization in the field, hence obtained recapitulation result of fertilization performance as in Table 5.

TABLE 5
RECAPITULATION OF MECHANICAL FERTILIZER PERFORMANCE.

No	Performance parameter	Mechanical fertilization
1	Actual speed (m/s)	0,568
2	Effective capacity (ha/hour)	0,137
3	Working width (m)	0,75
4	Theoretical Capacity (ha/hour)	0,426
5	Field efficiency (%)	32,13
6	Basic cost (Rp/ha)	184.990,88
7	Break even point – *BEP (Ha/year)*	72,7
8	B/C Ratio	1,093
9	NPV (Rp)	7.139.779
10	Operator (Watt)	47,96
11	Used motor power (HP)	2,52
12	Available motor power (HP)	7
13	*Engine Noise level (dB)*	94,48
14	Durability of operator (jam)	4
Machine specification		
1	Weight (kg)	124
2	Total width (cm)	100
3	Length of the machine (cm)	240
4	Height of the machine(cm)	110
5	Number of fertilization path (row)	4

Figure 4. In field performance test

Figure 5.Fertilization result

Fertilizer Machine Simulation Program

The application program generated in this research is very easy to use. The design of the resulting application program can be seen in the following Figure, while the program listing in the next listing.

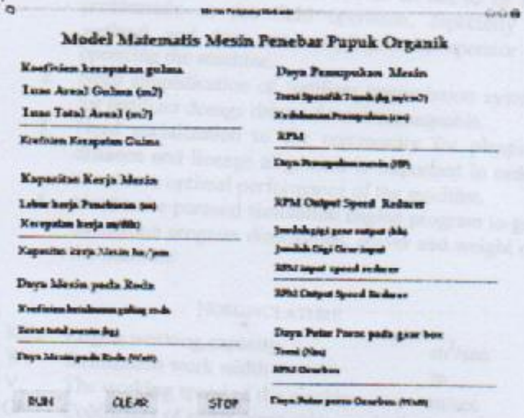

Figure 6 Simulation

While listing the program from the simulation of the fertilizer machine using Visual Basic programming languages are as follows;

```
Private Sub Command1_Click()
Dim NG As Single
Dim A As Single
Dim Wt As Single
Dim V As Single
Dim Cr As Single
Dim W As Single
Dim Ts As Single
Dim d As Single
Dim RPM As Single
Dim N1 As Single
Dim N2 As Single
Dim RPM2 As Single
Dim T As Single
Dim RPMGear As Single
```

```
NG = Val(Text1.Text)
A = Val(Text2.Text)
Wt = Val(Text4.Text)
V = Val(Text5.Text)
Cr = Val(Text7.Text)
W = Val(Text8.Text)
Ts = Val(Text10.Text)
d = Val(Text11.Text)
RPM = Val(Text12.Text)
N1 = Val(Text14.Text)
N2 = Val(Text15.Text)
RPM2 = Val(Text16.Text)
T = Val(Text18.Text)
RPMGear = Val(Text19.Text)
Koef = NG / A
Text3.Text = Str(Koef)
Ka = (Wt * V) / Koef
Text6.Text = Str(Ka)
P = (Cr * W * V) / 75
Text9.Text = Str(P)
Ps = Ts * d * Wt * RPM * ((2 * 3.14) / (75 * 60))
Text13.Text = Str(Ps)
RPM1 = (N1 / N2) * RPM2
Text17.Text = Str(RPM1)
PGear = T * (2 * 3.14) * (RPMGear / 60)
Text20.Text = Str(PGear)
End Sub

Private Sub Command2_Click()
Text1.Text = ""
Text2.Text = ""
Text3.Text = ""
Text4.Text = ""
Text5.Text = ""
Text6.Text = ""
Text7.Text = ""
Text8.Text = ""
Text9.Text = ""
Text10.Text = ""
Text11.Text = ""
Text12.Text = ""
Text13.Text = ""
Text14.Text = ""
Text15.Text = ""
Text16.Text = ""
Text17.Text = ""
Text18.Text = ""
Text19.Text = ""
Text20.Text = ""
End Sub

Private Sub Command3_Click()
End
End Sub
```

The results of data analysis in the relationship between the capacity of the fertilizer engine with the existing weed density in the test field can be seen in the graph below.

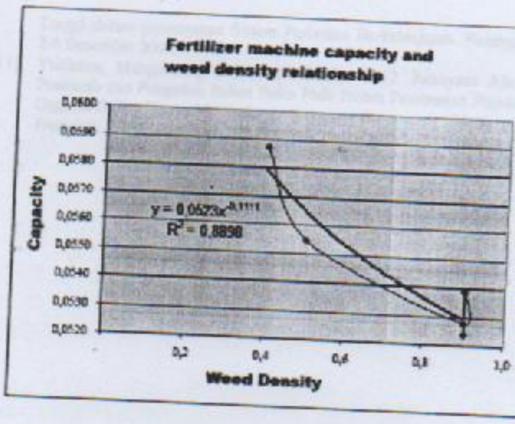

Figure 7. Graph of the relationship between the work capacity and the weed density in the field.

VI. FUTURE WORK

Based on the above performance test is recommended;

1. Weight machine to be reduced so as not to be too problematic in the field operation, especially in wetland, and does not complicate the operator in operating the machine.
2. Need simplification of fertilizer transmission system for fertilizer dosage dropped more manageable.
3. Need socialization to the community for planting distance and lineage alignment is important in order to achieve optimal performance of the machine.
4. Need to be pursued simulation engine program to get simulation program dimensions, power and weight of the machine

NOMENCLATURE

KKe	Engine working capacity	m^2/sec
Wt	fertilization work width	m
V	The working speed of the machine	m/sec
Cr	Coefficient of roller crane motor resistance	
W	total weight of fertilizer machine	kg
V	Speed of the fertilizer machine	m / sec
Ts	Torque specific soil	kg.m/cm^2
D	Depth / height falling fertilizer	cm
L	fertilization work width	cm
K ef	Effective capacity of tool	ha / hour
A	Area of cultivated land	Ha
T	Time for fertilization	hours
W	Theoretical work width	m
0.36	Conversion rate	
S	Path length	m
T	Travel time	seconds
Eff	Field Efficiency (%)	
BP	Cost of Goods	Rp / ha
BT	Fixed cost	Rp / year
T	Working hours	hour/year
BTT	Non-fixed cost	Rp / hour
K ef	Effective capacity	ha / hour
K Te	Theoretical working capacity	Ha / h
BEP	Break-even point	ha / year

BT Fixed cost Rp / year
BP Cost of goods Rp / ha
BTT Non-fixed cost Rp / hour
Kp Capacity ha / hour
hl Coefficient indicating the price of equipment rent is to get a profit of 10% of the cost of goods
RPM Speed Rotation
N1 Number of teeth in gear at output
N2 Number of teeth in gear at input
Mechanical power = In unit (HP)
Chemical power = In units (HP)
Unused fuel = In units (liters / hour)
∂ gasoline = thermal efficiency of gasoline fuel = 0.195
ρ gasoline = 0.725 (kg / lt)
The calorific value of gasoline = 10,000,000 (cal / kg)
4.2 = conversion number, 1 cal = 4.2 Joule
3600 = Unit Conversion, 1 hour = 3600 seconds
735 = Unit Conversion, 1 HP = 735 watts
π 2 Weed density coefficient
Σ Torque N.m

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