The Andhra Agric. J 62(1):190-197, 2015

Design and Evaluation of Push type Rotary Tiller

B Raj Kiran, N Rakesh, M Naga Jyothi and A Rama Rao
College of Agricultural Engineering, Agricultural College, Bapatla-522 101

ABSTRACT

A push type rotary tiller was designed and evaluated in the College of Agricultural Engineering, Bapatla during the year 2011-12. Rotary tiller consists of star wheel rotor and L-blade rotors mounted on front and rear side below the prime mover. These rotors gets drive form power source with the aid of chains and sprocket arrangement. Two towed wheels were used for transporting and a long length handle for guiding rotary tiller. The tiller was evaluated for its field capacities, field efficiency, weeding index and fuel consumption. These parameters were compared with setting 1(without font star wheel rotor drive and with rear L-blade rotor drive) and setting 2 (with front star wheel rotor drive and with rear L-blade rotor drive) of designed push type tiller. Effective field capacity, field efficiency, weeding efficiency and fuel consumption with setting 1 calculated as 0.022 ha/h, 85.13 %, 53.53% and 0.504 l/h respectively. Effective field capacity, field efficiency, weeding efficiency and fuel consumption with setting 2 were 0.0548 ha/h, 89.24%, 72.9% and 0.749 l/h respectively. The effect of push type tiller under setting 2 has given a wide range of variation during tilling operation when compared under setting 2. Hence it was observed that push type rotary tiller was more effective with front star wheel drive and rear L-blade drive and also effective in overcoming weed wrapping around the L- blade rotor.

Key words : Chain,Tiller, Field efficiency, L-blade rotor, Sprocket, Star wheel rotor, Weeding index.

Rotary tillers have become famous for preparation of seed bed in fields. This equipment is used for breaking or working the soil in lawns, gardens, Ahmad and Amran, (2004). Vertical axis rotary tiller was compared with horizontal axis rotary tiller for soil pulverization ad power requirements, Vertical axis rotors are mainly intended for secondary tillage as in fine seed bed preparation. Many types of blades and shapes of blades have been developed .L-type blades are better than hook shaped or pick-type blades in trashy conditions. Rotary weeder has higher weeding efficiency than the weeder with sweep blade. The cost of weeding by power weeder comes to only one-third of corresponding cost by manual labors Tajuddin A, (2006). The direction of rotation, depth of operation and the ratio of rotor peripheral speed and forward velocity (u/v) of rotary tiller are important from the design point of view Bernachi *et al.*, (1972). Rotation of tiller blades in the direction of travel is concurrent revolution and opposite to the direction of travel is reverse revolution.

MATERIAL AND METHODS

Design fabrication of push type tiller was carried out in College of Agricultural Engineering, Bapatla during the year 2011-12. Taking design parameters like (u/v) ratio and specific work in to consideration following is the procedure followed for selection of power source, chain drive - depending on velocity ratio, design of star wheel shaft, design of L-blade shaft, design of blades, selection of number of blades on rotor, rotor diameter, length of L-blade and width of L- blades are given below.

a) Available engine torque:

Selection of engine power was based on the average power required for water lifting by the farmers. Farmer can use the engine (dual fuel mode) for dual purposes for water lifting from tube wells as well as for prime mover in tilling the soil. Average selected engine was power was 1.1 kW, 1700 rated rpm of Honda make and fuel as (Petrol start and Kerosene run). Engine torque was calculated using following equation.

$$\text{Engine torque} = \frac{60 \times P}{2 \times \pi \times n} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

P= Power, Watt and n = rotational speed of active element, rpm.

Obtained engine torque was 6.18 N-m. This torque is not enough to till the soil and to maintain the (u/v) more than 1; speed was reduced to 220 rpm from 1700 rpm. Available and designed engine torque was 48 N-m.

b) Torque required for tilling the soil:
The volume of the soil cut can be calculated using the following equation.

Volume of Soil slice

$$V = h \times l \times b \quad \text{.................. (2)}$$

h = depth of operation, b = width of soil slice cut,

l= tilling pitch $= \left(\left(\dfrac{V_f}{u} \right) \times \dfrac{(2 \times \pi \times R_r)}{Z} \right)$

$V_{f=}$ forward speed, km/h, u = peripheral speed km/h, Z = number of blades on one plane and R_r = radius of rotation of active element, m

Net torque required for tilling the soil is the sum of the torque required for cutting soil slice, torque required for throwing cut soil, torque required for overcoming soil metal friction.

(i) Torque required for cutting soil

Force required for cutting the soil slice

$$F_c = \sigma_s \times A_s \quad \text{........................ (3)}$$

σ_s = shear strength of soil, A_s = area of shear failure= b × h

.....................................(4)

Hence torque required for cutting the soil slice

$$T_{is} = F_c \left\{ R_r - \left(\frac{h}{3} \right) \right\} = \sigma_s \times A_s \left\{ R_r - \left(\frac{h}{3} \right) \right\} \quad (5)$$

σ

(ii) Torque required for throwing the cut soil slices by centrifugal forces

Centrifugal force required for throwing the cut soil slices,

$$F_{cf} = \frac{(m_s \times u^2)}{R_r} \quad \text{..........(6)}$$

Torque required for throwing the cut soil slices,

$$T_{cf} = F_{cf} \left\{ R_r - \left(\frac{h}{3} \right) \right\} \quad \text{..........(7)}$$

Where, m_s = mass of soil slice cut

$$= V \times \rho \quad \text{..........(8)}$$

(iii) Torque required for overcoming soil metal friction

Frictional force between soil metal surfaces

$$= \mu_k \times m_s \times g \quad \text{..........(9)}$$

Torque required for overcoming soil metal friction,

$$T_{smf} = \mu_k \times m_s \times g \times R_r \quad \text{..........(10)}$$

Where, μ_k = coefficient of friction between soil-metal surface, g = gravitational acceleration.

$$\mu_k = \frac{1.09}{\sqrt{0.105 \times R_r \times n}} \quad \text{..........(11)}$$

Where, R_r = radius of rotation of active element, m, n = rotational speed of active element, rpm

Total torque required for useful work

$$= T_{is} + T_{cf} + T_{smf} \quad \text{.......... (12)}$$

Where, T_{is} = torque required for cutting the soil slice, T_{cf} = torque required for throwing the soil by centrifugal force, T_{smf} = torque required for overcoming soil metal friction.

c) Design of shaft:

The shaft was designed on the basis of strength, rigidity and stiffness. Design of shaft on the basis of load carried, which cause bending. Shaft may also undergo twisting moment. Hence the shaft should be designed under combined bending and twisting moments.

Torque T =

$$\frac{\pi}{16} \tau d^3 \quad \text{..........(13)}$$

Where T= Torque M-mm, τ = allowable shear stress, N/mm^2 and d= diameter of shaft, mm

Table 1. Permissible speed of smaller sprocket in rpm.

Type of chain	No. of teeth on smallerSprocket	Pitch of chain(P) in mm				
		12	15	20	25	30
Bush roller chain	15	2300	1900	1350	1150	1000
	19	2400	2000	1450	1200	1050
	23	2500	2100	1500	1250	1100
	27	2550	2150	1550	1300	1100
	30	2600	2200	1550	1300	1100

Table 2. Field efficiency of Push type rotary tiller.

Obser vation	Area (sq.m)	Setting 1(Without front drive)			Setting 2(With front drive)		
		E.F.C (ha/h)	E.F.C (ha/h)	Field efficiency (%)	E.F.C (ha/h)	E.F.C (ha/h)	Field efficiency (%)
1	25	0.019	0.024	79.25	0.057	0.064	90.00
2	25	0.025	0.028	88.19	0.054	0.059	90.78
3	25	0.023	0.026	87.96	0.052	0.060	86.94
		Averge		85.13	Averge		89.24

Table 3. Weeding effecieny of rotary tiller.

Obser vation	Area (sq.m)	Setting 1(Without front drive)			Setting 2(With front drive)		
		No. of weeds in 1m^2		Weeding efficiency (%)	No. of weeds in 1m^2		Weeding efficiency (%)
		Beofore weeding	After weeding		Beofore weeding	After weeding	
1	25	112	62	44.6	44	11	75.0
2	25	90	32	64.4	70	21	70.0
3	25	60	29	51.6	61	16	73.7
		Averge		53.53	Averge		72.9

Table 4. Fuel consumption of rotary tiller.

Obser vation	Setting 1(Without front drive)			Setting 2(With front drive)		
	Volume (ml)	Time (sec)	Fuel consumption (1/h)	Volume (ml)	Time (sec)	Fuel consumption (1/h)
1	67	473	0.509	30	156	0.692
2	49	353	0.499	33	166	0.715
3	53	383	0.498	40	171	0.842
	Averge		0.504	Averge		0.749

For uniformly distributed load,

$$\text{Bending moment} = \frac{wl}{8}$$

Where, w = total load, N and l= length of shaft, m

Bending Moment, M=

$$\frac{\pi}{32}\sigma_{max}d^3 \text{.......} (14)$$

Shaft subjected to combined twisting and bending moment and bending moment, the diameter of shaft obtained by using following equations.

Equivalent twisting moment

$$T_e = \sqrt{M^2 + T^2}$$

$$= \frac{\pi}{16}\tau d^3 \text{.......} (15)$$

Equivalent Bending moment

$$M_e = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right]$$

$$\frac{\pi}{32} \times \sigma_{max} \times d^3 = \frac{1}{2}\left[M + \sqrt{M^2 + T^2}\right] \text{.......} (16)$$

Where, T = torque N-m, M = bending moment N-m

Finally designed diameter of the shaft was 25 mm and length was 400 mm.

d) Selection of number of working sets of L-Blades:

Number of working sets I =

$$b_m / (b_1 \times 2) \text{.......} (17)$$

Where, b_m = working width of the machine, m, b1 = width of each blade, m

Number of blades in a rotary tiller $= I \times Z \times 2$.......(18)

Where, Z = 1= number of blades acting in one plane.

e) Selection of chain and sprocket:

(i) Selection of chain

Simplex chain was selected for transmitting power from one shaft to another shaft. According to power and speed of the smaller sprocket, pitch of the chain was selected. The pitch of chain was determined by ISO number i.e. 06B. The pitch of chain for 06B was 15 mm (Table.1). Number of chain links obtained was calculated from equation.20, as 70.

Length of the chain (L) = K.P............. (19)

Where, K= number of chain links, P = pitch of the chain

No .of chain links (K)

$$= \frac{T_1 + T_2}{2} + \frac{2x}{P} + \left[\frac{T_2 - T_1}{2\pi}\right]^2 \frac{P}{x} \text{.......} (20)$$

Where, x = Distance between two shafts, T_1 = no. of teeth on smaller sprocket and T_2 = no. of teeth on larger sprocket

(i) Selection of Sprocket

According to pitch and permissible speed, teeth on smaller sprocket were selected. The selected engine speed was 1700 rpm and pitch of the chain was 15 mm by using this data number of teeth on smaller sprocket was selected as 13 and number of teeth on larger sprocket was calculated. Number of teeth on larger sprocket was 100. 100 teeth on larger sprocket were not available. So, counter shaft was used to transmit power from engine to the L-blade rotor and star wheel rotor. Then selected numbers of teeth on larger sprocket were 36.

$$\text{Velocity ratio} = \frac{N_1}{N_2} = \frac{T_2}{T_1}$$

Where, N_1 = speed of rotation of smaller sprocket, rpm, N_2 = speed of rotation of larger sprocket, rpm

Performance evaluation of push type tiller

(i) Field Efficiency:

It is the ratio of effective field capacity to the theoretical field capacity expressed as percentage. It can be calculated by following equation

$$\text{Field efficiency} = \frac{\text{Effective field capacity } (E_e)}{\text{Theoritical field capacity} (E_t)} \times 100$$

(ii)Effective Field Capacity:

Effective field capacity is the ratio of actual area covered to the time consumed for real work and time lost for turning, adjustments etc. It can be calculated by following equation

$$E_e = \frac{A}{T_p + T_n}$$

Where, E_e = effective field capacity, (ha/h), A = Area covered (ha, T_p= Productive time (h)
T_n = Non- productive time (h).

(iii)Theoretical Field Capacity:

It is the rate of field coverage of the implement, based on 100 percent of time at the rated speed and covering 100 percent of its rated width.

$$E_t = \frac{width(m) \times speed(km/h)}{10}$$

(iv) Fuel Consumption:

Fuel tank is filled to full capacity before and after each test trial. The volume of fuel refilled after the test is the fuel consumption during the test. When filling up the tank, careful attention has taken to keep the tank horizontal and not to leave empty space in the tank.

Fuel Consumption

$$F_t = \frac{V(liters)}{t(hours)}$$

F = fuel consumption rate, l/h, V = volume of fuel consumed, L, t = total operating time, h

(v)Weeding efficiency: In this method the numbers of weeds or stubbles present which are counted before and after tilling with the help of throwing a square ring of 1 m × 1 m in the field according to standards. The weeding efficiency is expressed on percentage basis.

$$\text{Weeding effeciency}(\%) = \frac{W_B - W_A}{W_B}$$

Where, W_B = Number of weeds present per unit area before weeding operation.

W_A = Number of weeds present per unit area after the operation

f) Designed push type rotary tiller

(i) Frame:

It was made of G.I material of thickness 2 mm. It was used for connecting all parts at alignment. Boxed frames were made by welding two matching hollow rectangular pipe together to form a rectangular tube.

(ii)L-Blade:

L-shape blades with dimensions of thickness 75 mm × 40 mm × 3 mm are made with spring steel metal. This is used to cut the soil and mixes the weeds in the soil. The depth of tilling is about 4 cm can be obtained with these blades. The designed L-blade rotor with sprockets is shown in Plate.2.

(iii) Rotor:

Rotor is a cylindrical disc, which is connected to the L-blade shaft. L-blades are welded on the periphery of the rotor.

(iv) Star wheels:

Star wheels with dimensions of 200 mm×200 mm×3 mm (10 gauges) of metal sheet are used for making 200mm diameter of star wheel. The main function of star wheel is to cut the weeds to reduce the weed wrapping to L-blade rotor.

(iv)Transport wheel:

Transport wheels take the entire load, facilitating movement while transportation and supports a load. Diameter of the transport wheel is 300 mm, so that it can able to work in field at speed of 0.68 km/h. At this speed a farm operator can be able to work without any drudgery.

(v) Chain sprocket:

The reduction ratio between the counter shaft and engine sprocket is 2.76. The reduction ratio from counter shaft to the L-blades, star wheels is 2.76. L-blade rotor and star wheel rotor rotates at same speed i.e. 0.287 m/sec (1.033 km/h.). Simplex chain was selected for connecting the sprockets. The assembly of L-blade rotor with star wheel is shown fig.1.

(vi)Transmission system:

Power is transmitted from engine to counter shaft sprocket and power is reduced at reduction sprocket. Reduction sprocket is connected to L blade rotor sprocket and star wheel rotor sprocket and power is transmitted from reduction

Fig 1. Assembly of star wheels rotor and sprocket arrangement

Fig 2. Assembly of L-blade rotor and sprocket arangement

Fig 3. Designed Push type rotary tiller.

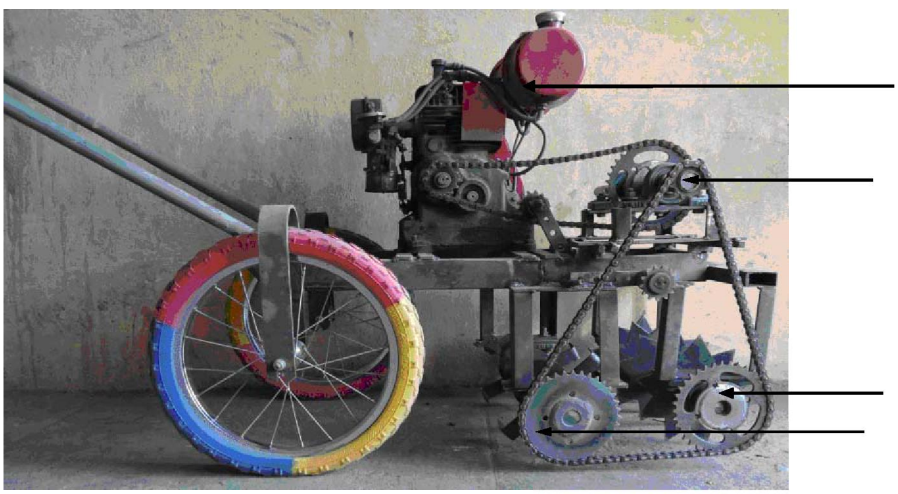


Fig 4. Field effeciency of psuh type rotary tiller.

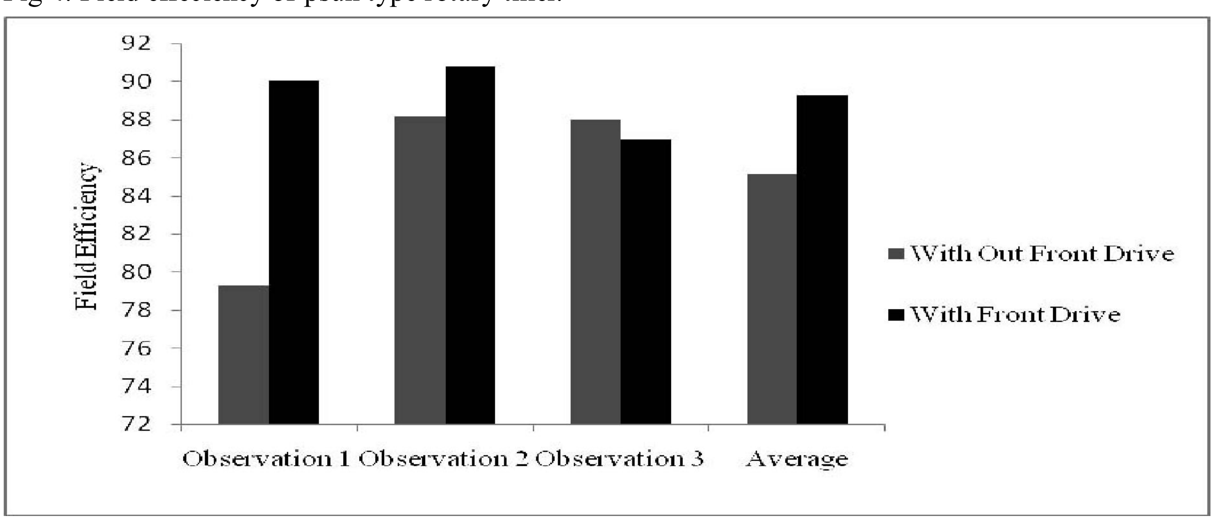


Fig 5. Effect of power given to front drive and without front drive to weeding efficiency.

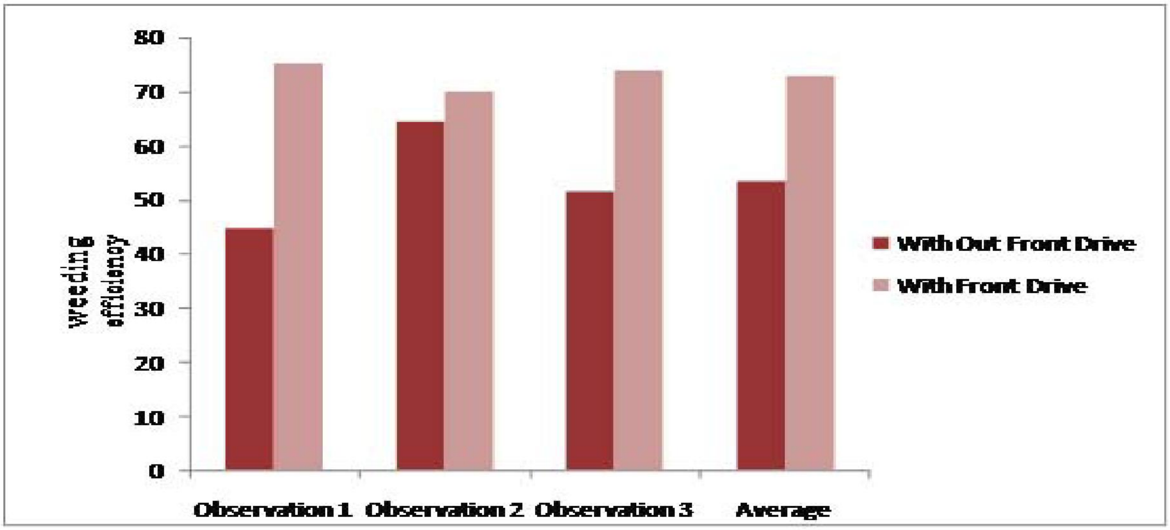
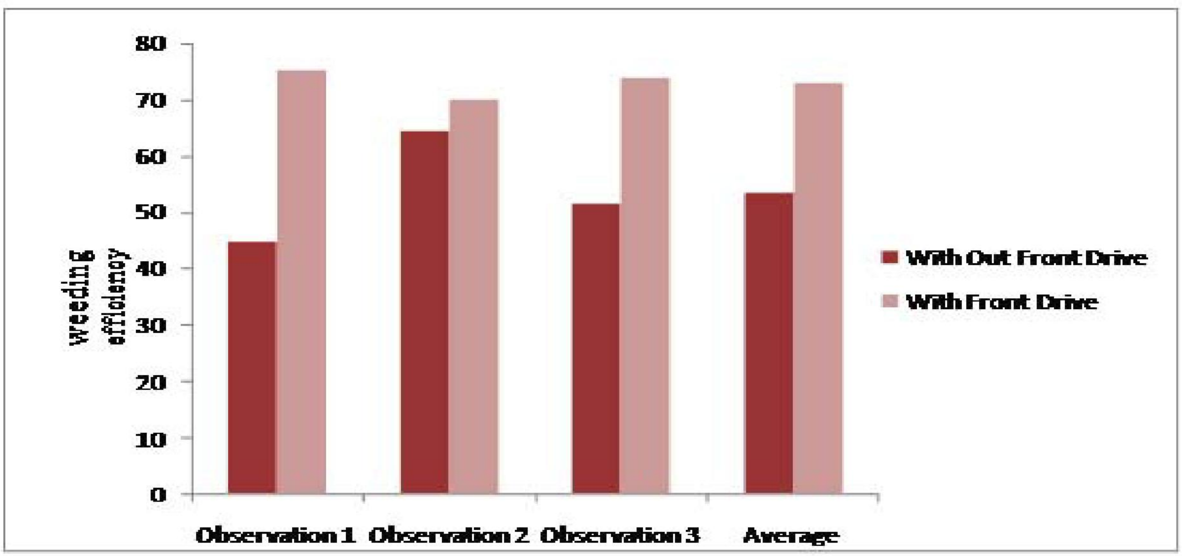


Fig 6. Fuel consumption of push type rotary tiller.



sprocket to working elements.. Designed push type rotary tiller was shown in fig.3.

RESULTS AND DISCUSSION

Field evaluation of push type rotary tiller was conducted in a plot near to the workshop in college of Agricultural Engineering, Bapatla. Tiller was evaluated for its performance in sandy soils.

(i)Field Efficiency of push type rotary tiller

The average of three replications was taken as field capacity. Effective Field Capacity (E.F.C) of the push type rotary tiller in setting 1(without front drive), setting 2 (with front drive) was 0.022 ha/h and 0.054 ha/h respectively. The calculation along with replications is shown in table 2. Variation in effective field capacity is due to, the thrust force of L-blades alone is not sufficient to move entire weight of machine in case of setting 2 (without front drive).

Theoretical Field Capacity (T.F.C) of push type rotary tiller setting 1 (without front drive), setting 2 (with front drive) was 0.0264 ha/h and 0.0614 ha/h respectively, table 2. Since the width is being constant, tiller without front drive has got reduced forward speed due to sinkage of star wheels. The plot showing the field efficiency under setting 1 and setting 2 are represent in fig.4.

(i) Weeding effeciency of push type rotary tiller

The average weeding efficiency in setting 1(without front drive) and setting 2 (with front drive) was 53.53 %. 72.9 % respectively shown in table 3. The weeding efficiency of tiller with front drive is more; this may be due to the sharp edges of star wheels assists in cutting the soil as well as weeds that are passing in front of L-blades. Weeds cut by the star wheels minimize the weed wrapping around the L-blade rotor, which increases the efficiency of weeding.

(i) Fuel consumption of push type rotary tiller

The fuel consumption of tiller Setting 1and setting 2 was 0.504 l/h. 0.749 l/h, respectively as shown in table.4. The fuel consumption is independent of area of tilling, but it depends upon the torque load upon the engine. The torque load upon the engine will be more, when the front star wheels drive is given that is under setting 2. Hence this effect results in the increase in fuel consumption of tiller under setting 2(with front drive) compared to the tiller without front.

CONCLUSIONS

The torque required for rotary tiller was 45 N-m and available engine torque was 48 N-m. The designed diameter of rotor was calculated as 25 mm with the running torque of 48 N-m. The field efficiency of the push type rotary tiller under setting 1 (without front drive) and setting 2(with front drive) was 85.13 % and 89.24 % respectively. The weeding efficiency of the push type rotary tiller under setting 1(without front drive) and setting 2(with front drive) was 53.53 % and 72.9 % respectively. The average fuel consumption of tiller under setting 1 and setting 2 was 0.504 l/h and 0.749 l/h respectively. The push type rotary tiller with setting 2 (with front drive) has more field efficiency and weeding efficiency. Hence rotary tiller with front drive is more effective than without front drive. In setting 2 (with font drive) weed wrapping to the rotor was minimized.

LITERATURE CITED

Ahmad D and Amran F A 2004 Energy prediction model for disk plow combined with a rotary blade in wet clay soil. International journal of engineering and technology 1(2): 102-114.

Bernacki H, Haman J and Kanafojski 1972 Agricultural machines theory and construction, Vol.1. Published by Scientific Publication Foreign Co-operation Center, CISTEI, Warsaw, Poland.

Raheman H and Sahu R K 2006 Design of tractor operated rotary cultivator- a computer simulation. Agricultural mechanization in Asia, Africa and Latin America 37(3): 27-31.

Tajuddin A 2006 Design, Development and testing of engine operated weeder. Agricultural engineering today 30(5, 6):25-29.

(Received on 13.03.2013 and revised on 26.06.2013)