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TILLAGE STUDIES AT IRRI

Emilio O. Casem
Asst. Agricultural Engineer

I. Power Tillers

A. Information about rotary power tillers
1. General cost and performance
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3. Usage
4. Important features about power tillers
5. Brands and distributors

B. Measuring the effective field capacity (efc) of rotary power tillers
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b. Total distance traveled
c. Effective area accomplished
d. Effective field capacity
e. Power requirement
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C. Use of big tractors

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B. Agricultural engineering department experiment
1. 1964 Wet Season
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b. Results
2. 1965 Dry Season
a. Procedure
b. Results

R E F E R E N C E S

1. Agric. Engrg. Dept., IRRI. Measuring the effective field capacity of rotary power tillers (leaflet). 1965.

2. Alicbusan, L. C. The rate of substitution of man-hours by animal- or machine horsepower-hours in rice production. 1964.

3. Bulanadi, J. Present methods of land preparation (and limitations of available) in the Philippines. 1963.

4. Casem, E. O. Review of the literature on the effect of depth of tillage on rice yield. 1964.

5. Domingo, R. G. Performance of rotary power tillers. 1965.

6. Johnson, L. Mechanization of Philippine farms. 1964.

7. _____. More farm power for more days of farm production per year. 1965.

8. _____. Power requirements in rice production. 1963.

9. Ramos, F. V. Cultivation methods and labor requirements presently used by the IRRI. 1963.

Table 1. Estimation of Effective Field Capacity of Rotary Power Tillers.*

(1) Average swath (or width of cut), S, in meters

$$S = \frac{W}{2N}$$

W = width of plot (in meters)
N = number of rounds
2 = number of trips per round

(2) Total distance traveled, D, in meters

$$D = \frac{A}{S} = 2NL$$

A = area of plot in sq. m. (length x width)

(3) Effective area accomplished, E, in square meters

$$E = wD = 2NLw$$

w = width of rotary tiller in meters

a. If width of swath is less than the rotary tiller's width, the operator has passed over part of the area twice to secure better coverage, therefore:

$$O = E - A$$

O = overlap (area which is rototilled twice)

b. If average width of swath is greater than the rotary tiller's width, the operator has left part of the area unrototilled, therefore:

$$U = A - E$$

U = unrototilled area (area missed)

(4) Effective field capacity, efc, in square meters per hour [1 hour = 60 minutes]

$$efc = \frac{60E}{T}$$

T = time used during the operation, in minutes

(5) Fuel consumption, C, in liters/hectare

$$C = \frac{10{,}000F}{E}$$

F = fuel used during the operation

(6) Power requirement, P, in HP-hours per hectare

$$P = \frac{10{,}000 \times ph}{efc}$$

ph = rated horsepower of power tiller

$$S = \frac{12.00 \text{ m}}{2 \times 12 \text{ rounds}} = 0.50 \text{ m} \quad - - - - - - - \quad 1$$

$$D = \frac{300.00 \text{ m}^2}{0.50 \text{ m}} = 600 \text{ m} \quad - - - - - - - - \quad 2$$

$$E = 0.60 \times 600 \text{ m} = 360 \text{ sq. m} \quad - - - - - - - \quad 3$$

$$O = 360 \text{ m}^2 - 300 \text{ m}^2 = 60 \text{ m}^2 \text{ (rototilled twice)} \quad - - - - \quad 3a$$

$$efc = \frac{60 \times 360 \text{ m}^2}{18 \text{ min.}} = 1200 \text{ m}^2/\text{hr} \quad - - - - - - - \quad 4$$

$$C = \frac{10{,}000 \text{ m}^2 \times 0.52 \text{ liters}}{360 \text{ m}^2} = 14.55 \text{ liters/ha} \quad - - - \quad 5$$

$$P = \frac{10{,}000 \text{ m}^2 \times 8.5}{1200} = 70.83 \text{ hp-hr/ha} \quad - - - - - - \quad 6$$

Average depth of tillage = 10 cm.

Continuation of

Table 1. Estimation of Effective Field Capacity . . . . .

$$S = \frac{12.00\ m}{2 \times 7\text{-}1/2\ \text{rounds}} = 0.80\ m \quad \text{- - - - - - -} \quad 1$$

$$D = \frac{300.00\ m^2}{0.80\ m} = 375\ m \quad \text{- - - - - - - -} \quad 2$$

$$E = 0.60\ m \times 375\ m = 225\ \text{sq m} \quad \text{- - - - - -} \quad 3$$

$$U = 300\ m^2 - 225\ m^2 = 75\ m^2\ \text{(left untilled)} \quad \text{- - - -} \quad 3b$$

$$efc = \frac{60 \times 225\ m^2}{12\ \text{min}} = 1125\ m^2/\text{hour} \quad \text{- - - - - -} \quad 4$$

$$C = \frac{10{,}000\ m^2 \times 0.35\ \text{liters}}{225\ m^2} = 15.56\ \text{liters/ha} \quad \text{- - - -} \quad 5$$

$$P = \frac{10{,}000\ m^2 \times 8.5}{1125} = 75.56\ \text{hp-hr/ha} \quad \text{- - - -} \quad 6$$

Average depth of tillage = 10 cm.

It is important to note that in both preparations the DEPTH OF TILLAGE and incorporation of VEGETATION should be verified and considered in addition to the WIDTH OF CUT or SWATH. The depth of tillage is taken by measuring the depth at different parts of the rototilled area.

* Taken from a leaflet "Measuring the Effective Field Capacity of Rotary Power Tillers" prepared by the IRRI Agric. Engrg. Dept., 1965.

Table 2. Use of Carabao Plowing and Harrowing at IRRI (Hours). 1965.

Month \ Dept.	Agron.	Var. Imp.	Expt. Farm	Entom.	Plant Path.	Plant Phys.	Ag. Eng.	Comm. & CAP	Ag. Eco.	TOTAL
January	137.5	180.5	46	67	29	26.5	--	--	--	486.500
February	39.875	1.5	-	11.875	10	--	--	--	--	63.250
March	60.75	36	85.5	15	--	--	11.875	--	--	209.125
April	10.625	65.875	68.875	11.75	--	1	5.625	2	--	165.750
May	81.375	47	23.5	39.625	25.562	3	5	--	1	226.062
June	100.125	1	14.5	35	9	22.187	10	4.375	--	196.187
T O T A L	430.250	331.875	238.375	180.250	73.562	52.687	32.500	6.375	1.000	1346.874

Grand Total (for 9 depts.) . . . 1,346.874

$$\text{Carabao-hours per day} = \frac{1346.874}{181} = 7.44 \text{ hours.}$$

9 26 65

Table 3. Power Requirements for Tillage in Rice Production in Manhours, Animal-Hours, and Rated Horsepower-Hours Per Hectare.*

OPERATION	MAN-HRS/HA			ANIMAL-HRS/HA			RATED HP-HRS/HA		
	Min.	Max.	Ave. range	Min.	Max.	Ave. range	Min.	Max.	Ave. range
Primary Tillage									
I. Animal Power									
Animal plow									
1. Wet soils	16	120	50-96	16	240	50-96	-	-	-
2. Dry soils	20	100	40-80	16	200	40-80	-	-	-
II. Power Tillers or Walking Tractors									
1. Wet soils									
Traction type 4 to 6 HP tractor & plow, in flooded soils	16	70	20-40	-	-	-	100	300	100-200
Traction type 4 to 6 HP tractor unit puddling tines, cage whls. & harrow, in soft soils	8	32	16-24	-	-	-	40	200	80-150
Rotary type power tiller, 5 to 10 HP	5	25	10-20	-	-	-	80	160	100-160
III. Standard Tractors 12 to 70 HP									
Disc or moldboard plow in moist to hard soil, tractor w/ std. rubber tires									
1. 10-20 HP	3	18	5-8	-	-	-	60	180	75-125
2. 20-30 HP	2	9	3-5	-	-	-	60	180	75-125
3. 40-60 HP	1	4	2-3	-	-	-	60	180	75-125
Offset hvy-dty disc harrow in dry rice soils (1 pass), 45-60 HP, rubber-tired or track type	1	2	1.2-1.6	-	-	-	50	100	70-90
Light duty tandem disc harrow, dry soils to pulverize the soil (1 pass) 30-45 HP rubber-tired tractor	0.8	1.2	-	-	-	-	50	100	70-90

Continuation of

Table 3. Power Requirements for Tillage .....

OPERATION	MAN-HRS/HA Min.	MAN-HRS/HA Max.	MAN-HRS/HA Ave. Range	ANIMAL-HRS/HA Min.	ANIMAL-HRS/HA Max.	ANIMAL-HRS/HA Ave. Range	RATED HP-HRS/HA Min.	RATED HP-HRS/HA Max.	RATED HP-HRS/HA Ave. Range
Vicon-Rotaspa rotary spade Model 210, 17 ft. width, for 20-35 HP tractor on heavy soils	-	-	3.3	-	-	-	30	40	-
Rotary tiller on dry soils	2	8	4	-	-	-	-	-	140
Rotary tiller & 35-60 HP tractor w/ cage whls., on wet soils	4	infinite in bad soils	4-32	-	-	-	100	infinite in bad soils	140-300
Moldbd. plow & 22-35 HP tractor	8.2	10	?	-	-	-	180	350	-
35 HP tractor with cage whls. for trampling soft soil (one pass), on field size 1000 m^2	4	?	-	-	-	-	140	?	-
" 2000 m^2	3	?	-	-	-	-	105	?	-
" no levees	2	?	-	-	-	-	70	?	-
Secondary Tillage									
I. Animal Power									
Buffalo & comb harrow, multiple pass	20	160	64-100	20	160	64-100	-	-	-
Animal-drawn wetland puddler, rotary type	8	33	-	16	66	-	-	-	-
II. Power Tillers or Walking Tractors									
4-6 HP traction type, w/ puddling whls. & comb harrow	8	32	16-24	-	-	-	40	200	80-150
Rotary tiller 5-10 HP "	5	25	10-20	-	-	-	50	160	100-160

III. Standard Tractors (please see section III, Primary Tillage).

* From a paper, "Power Requirements in Rice Production", by Loyd Johnson. 1963.

Table 4. Estimated Man and Horsepower Hours to Spade Plow, Disc, or Rotavate Flooded Heavy Clay to a Depth of 18 Cm with Various Size Power Units. *

Rated Horsepower of Unit RHP	Reasonable Range Operator Hours Per Hectare	Reasonable Range Horsepower Hours Per Hectare
0	200 - 333	0
1	40 - 67	40 - 67
2	22 - 37	44 - 73
3	15.4 - 25.6	46 - 77
4	11.7 - 19.5	47 - 78
5	9.5 - 15.8	48 - 80
6	8 - 13.3	48 - 80
7	6.9 - 11.5	48 - 80
8	6.1 - 10.2	48.5 - 81
10	4.9 - 8.2	49 - 82
15	3.3 - 5.5	49 - 82
20	2.5 - 4.2	49.5 - 82.5
30	1.65 - 2.7	49.5 - 82.5
40	1.24 - 2.06	49.7 - 83
50	0.99 - 1.65	49.8 - 83
60	0.83 - 1.38	49.8 - 83
70	0.71 - 1.18	49.9 - 83
80	0.62 - 1.04	49.9 - 83

FORMULA: $\text{Manhours/Ha.} = \frac{200 \text{ to } 333}{1 + 10\text{RHP } (40\%)}$

Horsepower-Hours/Ha. = Operator hours/Ha. x RHP of unit

* Taken from a paper, "Mechanization of Philippine Farms", by Loyd Johnson. 1964.

Table 5. Data on Effect of Soil Depth on Yield Per Hill of Tainan-3 (With Spacing of 30 cm x 30 cm), 1964 Wet Season. Non-Fertilized.

Soil Depth, cm	Ave. Ht. of Straw cm	Ave. No. of Tillers	No. of Mature Panicles	Straw Wt. g	Grain Wt. g	Plant Wt. g	N Content, Straw g	N Content, Grain g	N Content, Plant g
4	65.5	5.2	3.4	5.8	8.2	14.0	0.035	0.101	0.136
8	67.7	6.1	5.0	11.6	12.4	24.0	0.062	0.142	0.204
12	70.2	7.5	6.4	13.7	18.2	31.9	0.068	0.206	0.274
16	72.4	9.9	6.4	18.5	20.8	39.3	0.097	0.243	0.340
20	74.2	10.9	6.9	22.1	23.2	45.3	0.137	0.272	0.409
24	76.8	11.6	7.8	23.8	26.4	50.2	0.149	0.341	0.490
28	78.8	12.7	8.1	27.9	27.9	55.8	0.198	0.398	0.596
32	78.8	13.1	7.4	30.2	26.8	57.0	0.228	0.373	0.601
36	79.5	13.7	8.3	29.9	29.8	59.7	0.233	0.459	0.692

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Table 6. Data on Effect of Soil Depth on Yield Per Hill of PI-215936 (With Spacing of 15 cm x 20 cm), 1965 Dry Season. Non-Fertilized.

Soil Depth, cm	Ave. Ht. of Straw	Ave. No. of Tillers	No. of Mature Panicles	Straw Wt. g	Grain Wt. g	Plant Wt. g	N Content, Straw g	N Content, Grain g	N Content, Plant g
6	47.3	2.65	2.50	3.26	3.67	6.93	0.021	0.045	0.066
8	48.5	2.45	2.20	3.51	3.32	6.83	0.023	0.039	0.062
10	49.2	2.40	2.40	3.66	3.53	7.19	0.024	0.043	0.067
12	48.3	2.85	2.85	4.29	4.34	8.63	0.027	0.055	0.082
14	49.8	3.25	3.25	5.44	5.28	10.72	0.030	0.066	0.096
16	52.2	3.85	3.80	6.80	6.86	13.66	0.037	0.092	0.129
18	55.4	3.90	3.90	7.66	7.47	15.13	0.040	0.095	0.135
20	55.6	4.30	4.20	8.48	7.86	16.34	0.047	0.092	0.139
22	57.2	4.55	4.35	9.09	9.00	18.09	0.049	0.116	0.165
24	57.5	4.95	4.85	11.23	9.79	21.02	0.057	0.123	0.180
26	60.3	5.20	5.05	11.36	10.91	22.27	0.060	0.143	0.203
28	61.9	5.70	5.40	12.08	12.18	24.26	0.067	0.161	0.228
30	62.0	5.90	5.15	12.92	11.84	24.76	0.071	0.150	0.221
32	63.4	5.80	4.95	12.87	11.45	24.32	0.072	0.142	0.214
34	67.0	6.10	5.90	13.71	14.85	28.56	0.079	0.207	0.286
36	67.3	6.80	6.40	15.19	16.41	31.60	0.091	0.223	0.314
38	67.7	6.60	6.10	15.97	16.46	32.43	0.102	0.221	0.323
40	68.0	6.50	6.00	15.66	16.42	32.08	0.094	0.224	0.318

Table 7. Data on Effect of Soil Depth on Yield Per Hill of PI-215936 (With Spacing of 15 Cm x 20 Cm). Non-Fertilized and Fertilized. 1965 Dry Season.

Soil Depth, cm	Straw Height cm		Average Tillers		Straw Weight g		Panicle Dry Wt. g		Plant Weight g	
	NF	F	NF	F	NF	F	NF	F	NF	F
6	52.90	61.65	4.50	8.95	7.15	16.75	6.95	13.45	14.10	30.20
8	52.55	64.95	4.45	8.15	6.90	14.55	6.35	12.10	13.25	26.65
10	57.05	64.45	4.30	8.35	7.30	17.60	6.75	11.50	14.05	29.10
12	58.35	70.00	4.85	8.25	8.50	17.10	7.90	12.65	16.40	29.75
14	59.30	68.75	5.85	9.85	10.55	20.45	9.30	15.35	19.85	35.80
16	60.20	71.95	5.55	7.80	9.55	17.35	9.25	14.05	18.80	31.40
18	63.60	73.60	7.00	9.85	13.35	23.90	11.75	14.30	25.10	38.20
20	67.40	74.05	7.95	9.25	14.90	21.15	11.10	14.50	26.00	35.65
22	70.80	77.45	7.80	8.80	15.20	22.00	13.30	12.75	28.50	34.75
24	68.70	78.20	8.75	9.45	17.80	22.95	12.55	16.30	30.35	39.25
26	72.90	77.30	8.20	10.55	18.40	26.50	12.60	14.25	31.00	40.75
28	75.20	79.70	7.90	8.35	19.10	22.40	13.55	13.70	32.65	36.10
30	75.75	81.60	7.25	9.80	18.70	27.30	13.40	14.95	32.10	42.25
32	75.75	81.55	7.65	10.20	19.05	28.75	14.95	17.55	34.00	46.30
34	78.75	84.70	7.30	9.25	18.20	24.40	14.75	15.65	32.95	40.05
36	74.75	80.90	8.65	9.70	20.80	26.50	17.55	16.20	38.35	42.70
38	75.55	83.95	7.40	9.15	18.50	24.20	15.85	16.40	34.35	40.60
40	77.65	82.60	7.65	10.85	19.70	27.25	15.85	17.95	35.55	45.20
42	78.40	82.45	7.25	9.95	17.95	27.85	12.90	17.85	30.85	45.70
44	76.30	82.65	8.25	9.00	21.35	25.35	16.90	16.55	38.25	41.90
46	81.10	83.00	7.35	9.75	18.30	27.25	15.75	16.60	34.05	43.85
48	79.05	80.15	7.15	9.85	19.60	24.30	16.40	15.30	36.00	39.60
50	82.70	86.90	7.15	9.30	19.85	25.45	17.15	18.00	37.00	43.45
52	79.65	86.05	7.20	8.80	18.15	24.05	17.00	18.30	35.15	42.35
54	85.30	79.65	7.55	10.10	21.10	29.60	18.00	17.45	39.10	47.05
56	81.60	80.95	7.85	8.20	21.25	21.10	18.25	13.70	39.50	34.80
58	79.70	82.95	8.00	9.50	21.30	27.35	17.05	15.05	38.35	42.40
60	78.45	82.00	7.20	9.55	20.50	25.65	15.65	17.70	36.15	43.35
62	81.80	82.75	8.15	10.00	21.45	26.80	19.95	18.55	41.40	45.35
64	81.95	81.80	7.60	9.75	21.95	25.90	16.20	17.75	38.15	43.65
66	79.85	85.60	7.60	9.25	21.10	25.40	16.50	17.40	37.60	42.80
68	81.90	86.00	7.05	9.50	21.20	25.90	17.40	18.65	38.60	44.55
70	80.45	82.35	7.10	8.90	17.60	25.70	17.25	16.50	34.85	42.20
72	79.65	82.70	7.85	10.25	20.70	30.60	16.75	21.25	37.45	51.85
74	79.60	78.25	10.50	11.75	29.30	36.45	17.55	19.00	46.85	55.45

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Continuation of

Table 7. Data on Effect of Soil Depth on Yield Per Hill of PI-215936 (With Spacing of 15 Cm x 20 Cm). Non-Fertilized and Fertilized. 1965 Dry Season.

Soil Depth, cm	Grain Weight at 14% M.C., g NF	Grain Weight at 14% M.C., g F	N Content Grain, g NF	N Content Grain, g F	N Content Straw, g NF	N Content Straw, g F	N Content Plant, g NF	N Content Plant, g F	N Content Plant (F-NF) Kg. N/Ha
6	6.10	11.81	0.066	0.129	0.037	0.090	0.103	0.219	38.7
8	5.58	10.62	0.059	0.109	0.032	0.068	0.091	0.177	28.7
10	5.93	10.10	0.060	0.101	0.033	0.098	0.093	0.199	35.3
12	6.94	11.10	0.076	0.127	0.038	0.097	0.114	0.224	36.7
14	8.16	13.47	0.095	0.160	0.049	0.107	0.144	0.267	41.0
16	8.12	12.33	0.089	0.137	0.038	0.092	0.127	0.229	34.0
18	10.31	12.55	0.109	0.130	0.068	0.164	0.177	0.294	39.0
20	9.74	12.73	0.116	0.153	0.076	0.144	0.192	0.297	35.0
22	11.68	11.19	0.124	0.126	0.080	0.154	0.204	0.280	25.3
24	11.02	14.31	0.125	0.164	0.094	0.161	0.219	0.325	35.3
26	11.06	12.51	0.129	0.151	0.114	0.207	0.243	0.358	38.3
28	11.89	12.03	0.141	0.148	0.122	0.200	0.263	0.348	28.3
30	11.76	13.12	0.135	0.166	0.117	0.234	0.252	0.400	49.3
32	13.12	15.41	0.156	0.213	0.120	0.278	0.276	0.491	71.7
34	12.95	13.74	0.157	0.184	0.128	0.230	0.285	0.414	43.0
36	15.41	14.22	0.194	0.192	0.152	0.259	0.346	0.451	35.0
38	13.91	14.40	0.180	0.196	0.135	0.228	0.315	0.424	36.3
40	13.91	15.76	0.177	0.228	0.154	0.307	0.331	0.535	68.0
42	11.32	15.67	0.150	0.215	0.162	0.301	0.312	0.516	68.0
44	14.83	14.53	0.201	0.213	0.185	0.252	0.386	0.465	26.3
46	13.83	14.57	0.191	0.205	0.165	0.268	0.356	0.473	39.0
48	14.40	13.43	0.212	0.182	0.164	0.272	0.376	0.454	26.0
50	15.05	15.80	0.210	0.220	0.164	0.290	0.374	0.510	45.3
52	14.92	16.06	0.190	0.227	0.159	0.254	0.349	0.481	44.0
54	15.80	14.32	0.226	0.215	0.192	0.338	0.418	0.553	45.0
56	16.02	[illegible]	0.227	0.175	0.202	0.207	0.429	0.382	-15.7
58	14.97	13.21	0.216	0.184	0.194	0.273	0.410	0.457	15.7
60	13.74	15.54	0.186	0.226	0.190	0.273	0.376	0.499	41.0
62	17.51	16.28	0.244	0.226	0.208	0.281	0.452	0.507	18.3
64	14.22	15.58	0.202	0.224	0.192	0.274	0.394	0.498	34.7
66	14.48	15.27	0.191	0.219	0.190	0.263	0.381	0.482	33.7
68	15.27	16.37	0.214	0.237	0.189	0.253	0.403	0.490	29.0
70	15.14	14.48	0.220	0.216	0.146	0.280	0.366	0.496	43.3
72	14.70	18.65	0.205	0.270	0.188	0.322	0.393	0.592	66.3
74	15.40	16.68	0.222	0.245	0.268	0.420	0.490	0.665	58.3
									Mean 38.21

APPENDIX I

Brands of Rotary Power Tillers Distributed in the Philippines

DAIKIN	Overland Automotive Dist. 350 Quezon Blvd. Ext. Quezon City
FUJI	Clinton (Phil.) Distributing Co., Inc. Muelle del Banco Nacional & T. Pinpin, Manila
FURUKAWA	Peñala Commercial 702 Roman Santos Bldg. Plaza Goiti, Manila
HAKO	Philippine Factors, Inc. 48 Sta. Mesa Blvd. Quezon City
HINOMOTO	Getz Bros & Co., Inc. Pasong Tamo Ext. Makati, Rizal
ISEKI	Philman Products Marulas, Valenzuela, Bulacan Radiowealth Trading Corp. 311 P. Casal, Manila
KUBOTA	E. R. Angeles & Co. 327-329 Echague St. M a n i l a
LANDMASTER	Singer Sewing Machine Co. Bonifacio Drive Port Area M a n i l a
MITSUBISHI	SEA Commercial Co., Inc. 683 Sales St., cor. Soler M a n i l a
SATOH	Rural Machineries Co. Rizal Ave.-Lopez Jaena San Pablo City
YANMAR	Pacific Star, Inc. 1033-1035 R. Hidalgo Quiapo, Manila

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APPENDIX II

MEASURING THE EFFECTIVE FIELD CAPACITY (efc) OF ROTARY POWER TILLERS *

1. Things needed in testing for effective field capacity
   a. Watch
   b. Meter stick or zigzag (folding) rule
   c. Graduated cylinder
   d. Bamboo or wooden pegs
   e. Pencil and paper

2. Procedure in getting field data
   a. Layout, measure and record the area to be tilled
   b. Record the number of rounds and any fraction thereof (if less than a round) that completed the tillage
   c. Record the total time used
   d. Record the fuel used. This is determined by filling the fuel tank before starting work, then refilling after the work is finished. The number of liters put in during the refilling is the quantity used.
   e. It is important to note that the DEPTH OF TILLAGE and INCORPORATION OF VEGETATION should be verified and considered in addition to the width of cut or swath. The depth of tillage is taken by measuring the depth of different parts of the rototilled area.

* Taken from the leaflet, "Measuring the Effective Field Capacity of Rotary Power Tillers", prepared by the IRRI Agric. Engrg. Dept., 1965.