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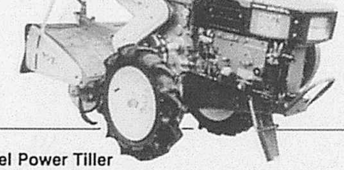

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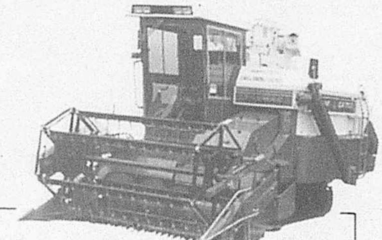

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EDITORIAL

Problems in 21st Century

Now we are in the new 21st century. During the 20th century, the world population increased to be 6 billion, nearly four times as large as that of the beginning of the 20th century, which still continue to grow at the ratio of 0.1 billion per year. The development of science technology brought about enormous power to mankind which had never been experienced before. This power was of great benefit to mankind, but at the same time, it caused many big disasters like atomicbombs at Hiroshima and Nagasaki. Economic and social gaps between the strong and weak nations, between the north and south has much expanded in the 20th century, which is producing unfavorable tension and disputes in many places of the world. In developing countries more than 1 billion people are starving, while leftover food is being thrown away in advanced nations.

Agricultural technology, especially mechanization of agriculture has achieved remarkable development in advanced nations in the past century, which raised the productivity to a great extent. Yet there are many places where almost all farmworks are done manually without power tool. How is it possible to provide farmers in developing countries with technological means to raise their productivity step by step? This remains to be the most important problem in the 21st century.

In the past century the world agricultural industries focused on advanced nations, but in the new century developing countries will take more leading part in the development of world agricultural industries as their potential demand is actualized.

AMA wishes to contribute to the development of world agriculture with support of all readers and contributors also in the 21st century.

Yoshisuke Kishida

Chief Editor

Tokyo, Japan
January 2001

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Development and Evaluation of an Active - Passive Tillage Machine

by

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Abstract

An active-passive tillage machine consisting of 16 rotor active elements and four passive elements with provision to change the depth of passive tool with respective to active tool and also rotor speed was developed. Studies were conducted in the field (black clay loam soil) by varying the forward velocity (3 levels). The results obtained for the different combination of active and passive tillage tools (5 levels) were computed and analyzed. The following conclusions were drawn.

The effect of all active-passive tools had significant influence on draft at all levels of forward velocity. For the passive tool, the slip increased steadily as the forward speed was increased. But for the active-passive tools, the rate of increase in slip was less due to the negative draft produced by the active tool. Variation in fuel consumption was noted among the tools and the reduction in fuel consumption was 20 percent for active + four passive elements as compared to that of four passive elements. The torque required to operate the active tool increased by 15 percent as the forward velocity was changed from 0.53 to 1.25 m/s. The DBHP required for the active tool decreased beyond a forward velocity of 0.7 m/s and reached zero at 1.03 m/s for the active tool. For the passive tool, the DBHP required increased steadily as the forward velocity was increased. The PTO power required to operate the active tool was greater than when it was combined with the passive tool. For the active + four passive elements combination, the rate of increase in PTO power required was less than when the forward velocity was increased beyond 0.8 m/s. As the forward velocity was increased, the total power required increased steadily for passive and combination of active-passive tools. The energy, time and cost of operation for the active-passive tillage tool was less by 64.7 to 71.3, 61,7 to 69.9 and 62.2 to 70.3 percent, respectively, as compared to the different implement combinations to obtain almost the same quality of tilth.

Introduction

With an annual production of 210,000 four-wheel farm tractors during 1996-97, India has emerged as the world's largest tractor manufacturer (Singh, 1997). India now has a population over 1.6 million tractors. As a global power in the international tractor industry, India must ensure efficient utilization of such a heavy investment in the agricultural engineering inputs. The agricultural engineering industry in India should not merely aim at the supply of tractors alone, but should put in place the systems needed to ensure their sustainability. The system should cover areas such as a complete range of matching implements for different agricultural operations, cost and energy efficient utilization of resources. Efficient utilization of high value capital intensive equipment will reduce the down time and cost of operation.

Rotary Tillage

The rotary cultivator is widely considered a most important tool as it provides fine degree of soil pulverization enabling the necessary rapid mixing of soil besides reduction in traction demanded by the tractor driving wheels due to the ability of the soil working blades to provide some forward thrust to the cultivating outfit (Beeny and Khoo, 1970). Nearly for all the tillage tools, a draft force is applied to the tool which causes the elements to move through the soil. The power developed by the engine is transmitted through the tyre-soil interface and the tractor drawbar. Due to the poor efficiency of power transmission at the tyre-soil interface, tillage energy efficiency were low. Also, because tractors require considerable weight to provide the necessary traction, soil compaction may occur. When this is the case, increased power is required in order to overcome the rolling resistance of the tractor tyre. Tillage tools which use only active (rotary powered) elements generally till a greater volume of soil than is required in most field crop systems and, therefore, require considerable power per unit width. But powered (active) tools result in negative draft (forward thrust) that may require further energy inputs to control tractor steering and three-point hitch and also may be harmful to the tractor drive train (Wismer et al., 1968). Hendrick and Gill (1974) reported that a rotary tiller can be operated under conditions beyond those for which it was designed. Febo and Gherbezza (1994) compared the performance of three types of ploughs and identified the advantages of rotary implement. Report of the Sub-group (1996) on Agricultural Implements and Machinery for the formulation of the Ninth Five-Year Plan had identified tractor drawn rotavator as one of the new equipment for Government assistance. In this paper, the development of an active- passive tillage machine and its performance evaluation are presented.

Review of Literature

Early tillage machines which combined active and passive tillage tools generally contained active tools which tilled the whole width of the machine. Also, the elements of a passive tool of a few machines were not strategically positioned as they were usually located in the tilled soil after the active tool (Chamen *et al.*, 1979, Wilkes and Addai, 1988). Hendrick (1980) built and tested a single rotor-powered active tillage machine. He compared the power requirements of a passive chisel tyne with that of the powered rotor operating at the same depth. Araya *et al.* (1987) built a single rotor active tillage machine similar to Hendrick's (1980). The active- passive tillage machine used by Shinners *et al.* (1990) had active tools that did not till the whole width of the machine but rather only tilled narrow zones very similar to a conventional chisel plough. The passive tool on this machine was positioned to till the soil left untilled by the active tool. Weise (1993) used a combined tillage machine consisting of wings for loosening the soil up to 200 to 250 mm and the rotor follows the wings working at about 100 mm. The clods in the top layer are crushed and a layer of fine soil is produced which is suitable for seeding. Preloosening the soil reduces the power requirement of the following rotor, although the major part of the energy saved at the rotor must be used for drawing the wings. Talarczyk (1994) discussed the development of cultivators with both active and passive tillage tools and illustrated number of examples.

Combined Tillage Machine with Active and Passive Tools

Purely active tillage machines return power to the tractor's drawbar by pushing the tractor. This may result in an overload of the PTO drive line and a reverse torque on the drive axle transmission. Additionally, because of the geometry of the line of action of the negative draught, weight transfer takes place from the rear to the front axle which increases the rolling resistance requirements of the tractor (Wismer et al., 1968). A way to control this detrimental forward thrust is to combine active and passive tools such that the forward thrust produced by the rotary powered tool contributes towards the power requirements of the passive tool. It appears that a tillage machine that combines active and passive tools has considerable promise as a means of reducing the draft and specific energy requirements of tillage operations, improving productivity by reducing tractor wheel slip and reducing soil compaction by the tractor drive tyres. Hendrick (1980) estimated an overall average power transmission efficiency of 82 percent for PTO-powered active tillage elements and 49 percent for drawbar passive tillage elements. According to Shinners et al. (1993) the potential benefits of combining active and passive tillage tools are:

i. Power for tilling the soil can be transmitted to the tillage tools through a mechanical power train more efficiently than through the tyre-soil interface;
ii. The negative draft of the active elements can be used to provide some or all of the draft requirements of the passive elements;
iii. Reduced draft of the tillage tools will result in less wheel slip and improve field productivity;
iv. Reduced draft of the tillage tools will allow the use of lighter tractors to reduce soil compaction and possibly reduce tractor cost; and
v. Reduced draft of the tillage tools will allow operations to be performed in more difficult traction conditions.

A potential drawback of a combination tool is that tillage tools become more complex and would change from machines with virtually no moving parts to machines with gear boxes, chains, bearings and shafts. This could increase their cost and reduce reliability. However, the combination tillage tool will not have drive components different from these successfully maintained on many other agricultural machines. Additionally, purely active tillage machines with similar drive train components have been successfully marketed for years. Kumar and Tiwary (1994) collected data from 19 tractor manufacturers in India and the analysis of the data showed that 21-30, 31-40 and 40-50 hp ranges account for 90 percent of all manufactured tractors. Seven manufacturers account for 90 percent of tractor production.

Even though there are research findings about the advantages such as reduced compaction due to less traffic, less energy consumption and cost when active and passive tools are used simultaneously in tillage operation, not many available studies have been conducted to investigate the influence of soil, machine and operational parameters on power requirements.

Materials and Methods

The Conceptual Development of the Active-passive Tillage Machine

Tools that get power from either tractor PTO or any other prime mover for the rotary, oscillatory or vibratory motion of its elements are classified as active tools. The speed of soil cutting by this tool is always higher than its travel speed. A tool that cuts the soil through its translatory motion is called passive tool. The speed of soil cutting by this tool is always equal to its travel speed. The conceptual development of active-passive tillage machine is explained below.

Construction of active tool-The active portion of the tool consists of mild steel pipe of diameter 110 mm and length 830 mm on which rotor blades were mounted such that 8 blades were facing left side and the remaining 8 blades facing right side. This method of arrangement off- sets the side thrust created by the bent portion of blades while cutting the soil. All the blades were fixed at an equal distance of 80 mm along the axis and at 30 degree division on the circumference of the pipe. Thus the 16 blades were mounted in six lines to distribute the load uniformly. On both ends of the rotor pipe, shafts were welded. The entire rotor assembly was mounted to the carrier frame on the top by means of bearings, bearing cups and side plates. On the right side shaft, provision was made to mount a duplex sprocket with keys. The front and side view of the machine are shown in **Fig.1**.

Power transmission-On the top of the carrier frame a right angled reduction gear box (3:1) and a torque transducer of 100 kg-m capacity were mounted in line parallel to the rotor axis. One end of the torque transducer was coupled to the reduction gear box and to the other end a duplex sprocket was mounted. The duplex sprockets mounted on the torque transducer and rotor at a center distance of 560 mm were connected by a pair of chains. The other end of the reduction gear box was connected to the tractor PTO while working in the field and to the power source provided in the soil bin loading car during testing. Thus any torque transmitted from the reduction gear box to the active tool (rotor drum) was only through the torque transducer. Three sets of duplex sprockets of 18, 27 and 36 teeth were provided. By fixing any two sprockets,18:36, 18:27, 27:36 and 27:18 speed ratios could be obtained. Thus for every 100 input speed to the reduction gear box, the rotary speed obtained in the rotor are: 16.67, 22.22, 25.00 and 50.00 rpm.

The Passive Tool

Manohar Jesudas (1994) studied the mechanics of chisel type shares and optimized its dimension for better performance with least draft. On that basis, the elements of passive tools were made of 73 mm × 18 mm mild steel flat of height 890 mm. At the bottom, a removable share of size 150 × 24 × 12 mm (length × width × thickness) was fixed at an angle of 110 degrees to the vertical. Each element of the passive tool was fixed to the carrier frame by means of two pins such that when the tip of the rotor blade touches (active element) the ground, the share points of the passive tool also touches the ground. Provision was also made to lower the passive tool with respect to rotor axis in steps of 50 mm.

Positioning the elements of the passive tool - Studies were carried out by research workers using various shapes and sizes of passive tool elements. Most of them used the passive tool in front of the active tool such that the passive tool performs the work of a primary tillage and active tool that of a secondary tillage. Shibano (1972), Kailappan

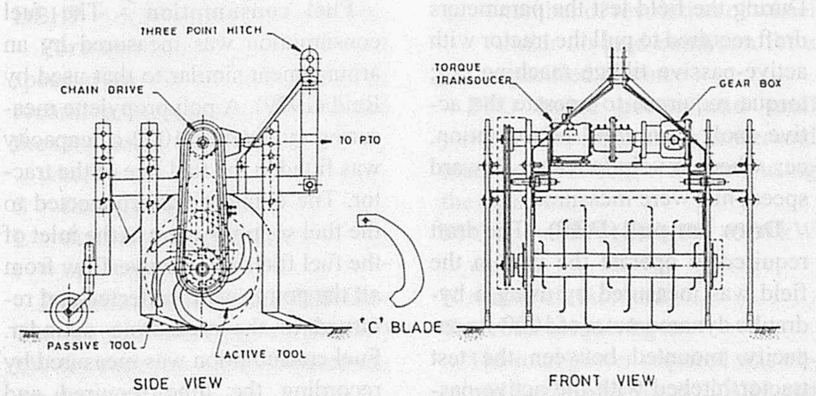

Fig. 1 Active-passive tillage machine.

Appendix: The active passive tillage machine in action.

Table 1. Specifications of the Active-passive Tillage Machine

Details	Quantity/Values
Number of active and passive elements	16 and 4
Diameter and length of active drum, mm	520 and 745
Distance between front passive elements, mm	830 (310 mm ahead of rotor axis)
Distance between rear passive elements, mm	121 (275 mm behind rotor axis)
Duplex sprockets (any two are used at a time)	3 - (18, 27, 36 teeth)
Reduction ratio in the right angled gear box	1:3
Active tool working depth, mm	150
Passive tool working depth, mm	Adjustable 150, 200 and 250
Weight of the unit, kg	320
Length × width × height, mm	1060 × 1290 × 1400

(1981), Nagaiyan (1983), Kumar and Manian (1986), Wilkes and Addai (1988) and Weise (1993) used the passive tool ahead of the active tool and at greater depth. They have not reported the interactive behaviour of active and passive tools. Chamen *et al.* (1979) mounted the deep chisel tynes behind the rotary unit to balance the forward thrust from the rotating blades. Shinners *et al.* (1990) placed the passive and active tools in line such that all the tools were working in the untilled soil. Shinners *et al.* (1993) placed two passive elements in the rear and in between the two rotors and two other passive elements in the front but at outboard.

Considering the above investigations, in the present study four passive elements were used. All of them were mounted outboard with two on either side of the rotor drum. The passive elements were fixed to the carrier frame: two in front and two at the rear such that both the active and passive tools operate in the untilled soil.

The Hitch System - A three-point hitch system was provided in the carrier frame such that the active-passive tillage machine could be mounted on either category I or category II of the three-point linkage of tractors. A cover was provided for the chain and sprocket transmission to protect them from the soil. An adjustable cover was provided behind the rotor to avoid throwing of soil far behind the unit. The specifications of the active-passive tillage machine developed are shown in the **Table 1**.

Field Test and Measurement

The field tests were conducted at the Tamil Nadu Agricultural University campus, Field No.36-E, with black clay loam soil.

The selected levels of variables were as follows:

i. Depth of active tool (da)=150 mm
ii. Depth of passive tool (dp) =200 mm
iii.Speed of operation of active tool, (Vr)= (3.68 m/s) 135 rpm (corresponding PTO rpm of 540 ± 20)
iv.Three forward speeds (V_f) = 0.53 (Vf_1), 0.73 (Vf_2) and (corresponding to rated engine rpm of 1600)1.25 (Vf_3) m/s

The treatments used were as follows:

i. 2 passive elements alone - P_2
ii. 4 passive elements alone - P_4
iii.Active tool alone - A
iv.Active tool + 2 passive elements $A + P_2$
v. Active tool + 4 passive elements $A + P_4$

Each test was replicated thrice. During the field test the parameters draft required to pull the tractor with active-passive tillage machine (kg; torque required) to operate the active tool, kgm; fuel consumption, cc; wheel revolution and forward speed, m/s were measured.

Draw bar pull (DBP) - The draft required to operate the unit in the field was measured by using a hydraulic dynamometer of 1000-kg capacity, mounted between the test tractor hitched with the active-passive tillage machine and the hauling tractor (Narayanarao and Verma, 1982; Sheruddin Bukhari *et al.*, 1992; RNAM, 1995). The test tractor was run with transmission in neutral and the PTO and the hydraulic system under fully operational conditions. The dynamometer was hitched to ensure a horizontal pull. First the draft required (F_1) to pull the test tractor along with active-passive tillage machine in lifted position was measured. Then the draft required (F_2) to pull the test tractor with active-passive tillage machine in working position was measured. Then the draft required to operate the active-passive tillage machine was calculated using the equation:

$$DBP = (F_2 - F_1), kg$$

Torque - On top of the carrier frame, a right angled reduction gear box (3:1) and a torque transducer of 100 kg-m capacity were mounted in line parallel to the rotor axis. One end of the torque transducer was coupled to the reduction gear box. To the other end, a duplex sprocket was mounted. The duplex sprockets mounted on the torque transducer and rotor at a center distance of 560 mm were connected by a pair of chains. The other end of the reduction gear box was connected to the tractor PTO while working in the field. Thus any torque transmitted from the reduction gear box to the active tool (rotor drum) was only through the torque transducer. The torque required to operate the active tool was measured by keeping digital load indicator on the tractor.

Fuel consumption - The fuel consumption was measured by an arrangement similar to that used by Reid (1979). A polypropylene measuring cylinder of 1000-cc capacity was fitted in the fuel line of the tractor. The cylinder was connected to the fuel supply system at the inlet of the fuel filter and the overflow from all the points were collected and returned to the measuring cylinder. Fuel consumption was measured by recording the time required and quantity of fuel consumed for a

Table 2. Field Performance Values at (Low First Gear) 0.53 m/s

Observed/ calculated values	Treatments/Tools					
	No Load	A	P_2	P_4	A+P_2	A+P_4
Distance, m	80.00	80.00	80.00	80.00	80.00	80.00
Time taken, s	150.00	154.30	161.50	168.80	162.00	168.53
Wheel revolutions, n	22.00	23.27	24.10	25.47	24.80	25.00
Fuel consumption, cc	110.00	233.33	160.00	191.67	271.67	230.00
Draft, N	1156.0	453.3	2813.3	3926.7	3102.3	3402.3
Rotor torque, N m		507.60	-	-	516.30	522.50
Forward speed, m/s	0.5333	0.5185	0.4954	0.4739	0.4938	0.4747
Forward speed, kmph	1.9200	1.8667	1.7835	1.7061	1.7777	1.7233
Slip,%	-	5.77	9.55	15.77	12.77	13.64
DBHP, kW	0.6132	0.2338	1.3863	1.8509	1.5237	1.6065
Fuel consumption × 10^{-3}, m^3/hr	2.6400	5.4439	3.5666	4.0877	6.0371	4.9131
DSFC, kg/kW hr	3.5303	19.0932	2.1093	1.8110	3.2489	2.5078
PTO Hp, kW	-	7.1406	-	-	7.2630	7.3502
Total power, kW	0.6132	7.3744	1.3863	1.8509	8.7867	8.9567
Time required, hr/ha		10.3020	-	-	7.8128	6.0459
Energy input, MJ/ha		2031.33	-	-	1708.38	1075.88
Energy utiilized, MJ/ha		273.50	-	-	247.14	194.95
Energy efficiency,%		13.46	-	-	14.47	18.12
Energy saved,%		-	-	-	15.90	47.04

specified length of run and then calculating the fuel consumption on an hourly basis using the equation:

$W_f = (36\, V_F \times 10^{-4}) / t$

where

W_f = fuel consumed, m^3/hr;

V_f = volume of fuel consumed for a specified length of run, cc and

t = time taken to cover a specified length of run, s

Drawbar specific fuel consumption (DSFC) - The drawbar specific fuel consumption of the tractor was calculated using the equation:

$DSFC = (W_f \times \rho_f) / DBHP$

where

DSFC = drawbar specific fuel consumption, kg/kW hr;

W_f = fuel consumed, m^3/hr;

ρ_f = density of fuel, kg/m^3 and

DBHP = drawbar horse power, kW

Forward speed - The forward speed of operation was calculated by recording the distance traveled and the time taken. S = L / t

where

S = forward speed, m/s;

L = distance traveled, m and

t = time taken, s

Drawbar horse power (DBHP) - The drawbar horse power, (DBHP) kW for each run was calculated using the equation:

$DBHP = 0.746\,(DBP)S / 75$

where

DBP = drawbar pull, kg and

S = speed of operation, m/s

Wheel slip - The slip of the tractor was measured by monitoring the number of revolutions of the wheel over a specified distance under load and zero load conditions. The revolutions made by the wheel was fed to a revolution counter through a cable used for the speedometer. The revolution counter was mounted at an appropriate height for easy observation. The slip was calculated using the equation:

$S' = 100\,(n_1 - n_0) / n_0$

where

S′ = wheel slip, percent;

n_1 = number of revolutions of wheel under load condition for a specified distance and

n_0 = number of revolution of wheel under no load condition for a specified distance

PTO horse power and total power - The PTO horse power and total power were computed using the equation:

PTO hp = 0.746 (2∏NT) / 4500 kW

where

N = rpm of rotor and

T = rotor torque, kg m

The total power required was obtained by the addition of DBHP and PTO horse power.

Statistical Analysis and Modeling

The mathematical models developed for the data obtained during the field test were:

i) $Y = f(X_1)$

where,

Y = draft, kg and

X_1 = forward velocity, m/s

ii) $Y = f(X_1)$

where,

Y = draft, kg and

X_1 = fuel consumption, kg/hr

iii) $Y = f(X_1)$

where,

Y = draft, kg and

X_1 = slip, percent

iv) $Y = f(X_1)$

where,

Y = torque, kg m and

X_1 = forward velocity, m/s

Comparative Performance and Cost

The cost of operation and energy required to operate the active-passive tillage tool were compared by conducting field experiments with combinations of implements. Different combinations of implements were selected to obtain similar soil tilth conditions as assessed in terms of bulk density as follows:

T_1 -Mould board plough + cultivator

T_2 -Mould board plough + cultivator + disc harrow

T_3 -Active- passive tillage tool

In order to assess the bulk density of the soil, core samples were collected at random places after the operation of each implement combination in the field by driving the tube core sampler of 50 mm in diameter and 100 mm long. The soil core samples obtained were oven-dried for 24 hours at 105°C, and weighed. The bulk density was calculated.

Results and Discussion

Field Performance Evaluation

The recorded average values of time taken, fuel consumed, wheel

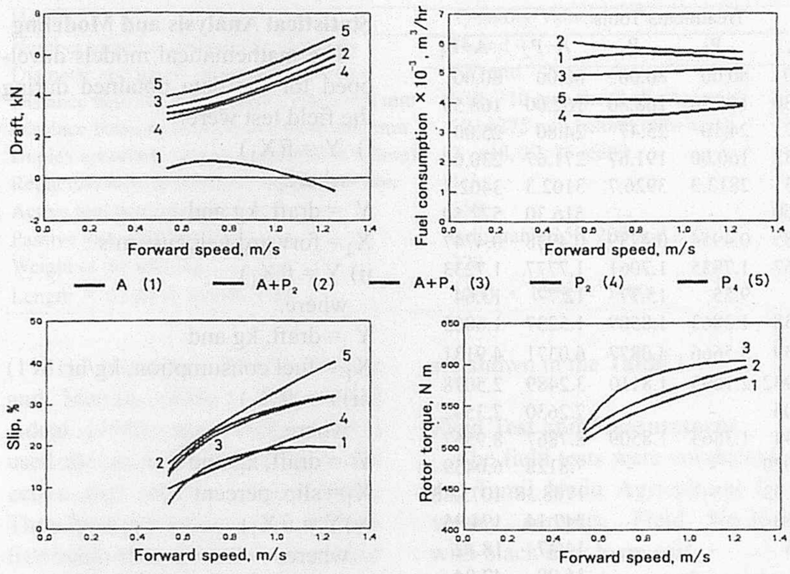

Fig. 2 First performance at different forward speeds.

Table 3. Field Performance Values at (Low Second Gear) 0.73 m/s

Observed/ calculated values	Treatments/Tools					
	No Load	A	P_2	P_4	$A+P_2$	$A+P_4$
Distance, m	92.00	92.00	92.00	92.00	92.00	92.00
Time taken, s	122.23	130.20	133.00	142.07	149.93	142.83
Wheel revolutions, n	25.27	29.17	28.83	31.30	30.80	31.07
Fuel consumption, cc	86.67	203.33	130.00	161.67	245.00	196.67
Draft, N	1215.7	805.3	3346.7	4443.0	3514.3	3886.0
Rotor torque, N m	-	536.80	-	-	548.40	574.10
Forward speed, m/s	0.7526	0.7066	0.6917	0.6476	0.6136	0.6441
Forward speed, kmph	2.7096	2.5438	2.4902	2.3312	2.2090	2.3188
Slip,%	-	15.43	14.09	23.86	21.88	22.95
DBHP, kW	0.9101	0.5660	2.3026	2.8772	2.1564	2.4896
Fuel consumption x 10^{-3}, m^3/hr	2.5527	5.6220	3.5188	4.0967	5.8827	4.9570
DSFC, kg/kW hr	2.3000	8.1449	1.2531	1.1676	2.2370	1.6327
PTO Hp, kW	-	7.5514	-	-	7.7146	8.0761
Total power, kW	0.9101	8.1174	2.3026	2.8772	9.8710	10.5657
Time required, hr/ha	-	7.5600	-	-	6.2874	4.4923
Energy input, MJ/ha	-	1539.43	-	-	1339.67	806.56
Energy utiilized, MJ/ha	-	220.92	-	-	223.43	170.87
Energy efficiency,%	-	14.35	-	-	16.68	21.19
Energy saved,%	--	-	-	-	12.98	47.61

revolutions, draft and torque required to operate the active-passive tools during a specified distance and the calculated values of forward speed, drawbar fuel consumption, slip, drawbar horse power and PTO horse power are presented in **Tables 2** to **4** for the low first, second and third gears, respectively.

Draft - The draft required to operate various tools at different forward velocities is shown in **Fig.2** which infers that the draft required for P_4 was great at all levels of forward velocities followed by $A+P_4$, $A+P_2$, P_2 and A. For all the tools, except for A, the draft increased with increase in forward velocity (Hendrick and Gill, 1971; Hoki *et al.*, 1988 and Salokhe *et al.*, 1994). The increase was great (96 percent) for P_2. But for A, a reverse trend was observed beyond 0.7 m/s which might be due to an increase in negative draft at higher forward velocity and consequent effect of increased bite length. The negative draft produced at low third gear was (-) 0.6053 kN. The analysis of variance showed that there was a significant difference among all the treatments, tools, forward velocities and all the first-order interactions. This showed interrelationships among each pair of variables which was reflected in the individual regressions. A comparatively high error mean square of 70.72 in field experiment showed the inability of homogenizing the treatment in field conditions which might be due to the inherent variability during the execution of the field trials.

Effect of forward velocity on draft - From the interaction of tools and forward velocity, it was observed that the effect of all active-passive tools had significant influence on the draft at all levels of forward velocity. The linear regression equations between draft (Y) and forward velocity (X_1) fitted for the tools are as follows:

i. For T = A, Y = 165.71 - 173^{NS}X1 and $R^2 = 0.77^{**}$

ii. For T = P_2, Y = 69.28 + $384^{**}X_1$ and $R^2 = 0.99^{**}$

iii. For T = P_4, Y = 160.72 + $416^{**}X_1$ and $R^2 = 0.99^{**}$

iv. For T = $A+P_2$, Y = 79.97 + $406^{**}X_1$ and $R^2 = 0.99^{**}$

v. For T = $A+P_4$, Y = 112.17 + $407^{**}X_1$ and $R^2 = 0.99^{**}$

When T= A, the correlation coefficient was significant at one percent level of probability whereas the regression coefficient was nonsignificant which might be due to the fact that although there was an association between Y and X_1, any more change in X_1 would not change Y, i.e., the levels already used in X_1 might be optimum. Moreover in order to know whether the association was perfect or not in all, the four other cases *viz.*, T= P_2, T= P_4, T = $A+P_2$ and T= $A+P_4$, instead of testing r, the t-test used for 1-r, gave a non-significant result which showed that r was one, i.e., the association was perfect. A comparison of all the above regression

Table 4. Field Performance Values at (Low Third Gear) 1.25 m/s

Observed/ calculated values	Treatements/Tools					
	No Load	A	P_2	P_4	$A+P_2$	$A+P_4$
Distance, m	84.00	84.00	84.00	84.00	84.00	84.00
Time taken, s	65.90	82.80	85.73	104.03	90.50	92.30
Wheel revolutions, n	23.43	28.03	29.40	32.90	30.97	31.00
Fuel consumption, cc	48.33	125.00	91.67	113.33	143.33	131.67
Draft, N	1308.7	-605.3	5527.0	6845.7	5926.0	6254.7
Rotor torque, N m	-	584.60	-	-	596.57	603.97
Forward speed, m/s	1.2747	1.0145	0.9798	0.8054	0.9282	0.9101
Forward speed, kmph	4.5890	3.6522	3.5273	2.8994	3.3415	3.2765
Slip,%	-	19.63	25.48	40.42	32.18	32.31
DBHP, kW	1.6593	-0.6138	5.3865	5.4841	5.4712	5.6620
Fuel consumption $\times$ 10^{-3}, m^3/hr	2.6402	5.4348	3.8494	3.9218	5.7015	5.1356
DSFC, kg/kW hr	1.3047	-	0.5860	0.5864	0.8545	0.7438
PTO Hp, kW	-	8.2238	-	-	8.3921	8.4962
Total power, kW	1.6593	7.6130	5.3865	5.4841	13.8633	14.1582
Time required, hr/ha	-	5.2655	-	-	4.1565	3.1792
Energy input, MJ/ha	-	1031.51	-	-	858.35	591.37
Energy utiilized, MJ/ha	-	144.31	-	-	207.44	162.04
Energy efficiency,%	-	13.99	-	-	24.16	27.40
Energy saved,%	-	-	-	-	16.79	42.67

equations shows that the effect of X_1 was almost identical in all four cases and ineffective for T = A only.

Slip - The variation in slip at different levels of forward speed for the tools studied is shown in **Fig.2**. For the passive tool, the slip increased steadily as the forward speed increased. But for the active tool and its combinations with the passive tool the rate of increase in slip was which indicates the role of negative draft produced by the active tool (Wilkes and Addai, 1988; Shinners *et al.*, 1990 and 1992). At all levels of forward velocity, the slip was maximum for P_4 (15.77 to 40.42 percent) and minimum for A (5.77 to 19.63 percent). At low first gear, the slip varied from 5.77 to 15.77 percent and at low third gear, it varied from 19.63 to 40.42 percent for the tools tested. The analysis of variance reveals a significant difference among the treatments, the tools and the forward velocities. The first-order interaction between the tools and forward velocity was insignificant. Moreover, the mean square error (MSE) was 28.9 which showed that the experiment was almost perfect. The perfectness might be a cause for the non-interaction.

Effect of forward velocity on slip - From the first-order interaction between the tools and different levels of forward velocity, it was inferred that in most of the cases, the tools had no effect on slip at different levels of forward velocity, except for A and P_4 which exhibited significant effect on the slip. The linear regression equations fitted between slip (Y) and forward velocity (X_1) are:

i. For T = A, Y = -0.410 + $16.8^{**}X_1$ and $R^2 = 0.78^{**}$
ii. For T = P_2, Y = 1.917 + $22.0^{**}X_1$ and $R^2 = 0.999^{**}$
iii. For T = P_4, Y = -1.293 + $33.6^{**}X_1$ and $R^2 = 0.99^{**}$
iv. For T = $A+P_2$, Y = 1.152 + $25.3^{**}X_1$ and $R^2 = 0.95^{**}$
v. For T = $A+P_4$, Y = 2.856 + $24.1^{**}X_1$ and $R^2 = 0.93^{**}$

The regression equation fitted for T = A as in the case of draft gave significant R, and the insignificant regression coefficient which might be due to the fact that X_1 had already been utilized to the optimum level. A comparison of the five equations showed that except for T = A the explanatory power of X_1 was almost perfect in the four other cases *viz.*, T = P_2, T = P_4, T = $A+P_2$ and T = $A+P_4$. Moreover, the change expressed by X_1 for Y was about 24 percent in T = $A+P_2$, T = $A+P_4$ and T = P_2 whereas it was higher than all the above three for T = P_4. But the validity was almost perfect.

Fuel consumption - **Fig.2** shows the requirement of fuel consumption at various forward speeds. From the figure, it can be concluded that for all the tools there was no increase in fuel consumption as the forward velocity was increased which might be due to the fact that the engine was operated at constant speed (1600 rpm) even though the forward velocity was changed due to change in gear position. But the variation in fuel consumption was noted among the tools which might be due to difference in power requirement for different tools. The fuel consumed by A+ P_2 was maximum (6.0371 m^3/hr) followed by A, $A+P_4$, P_4 and P_2 (3.566 m^3/hr). The average reduction between the maximum and minimum was 33 percent. The reduction in fuel consumption (20 percent) for $A+P_4$ as compared to A shows that the negative draft was better utilized by adding 4 passive elements (Chamen *et al.*, 1979; Hendrick, 1980; Nagaiyan, 1983; Kumar and Manian, 1986; Araya *et al.*, 1987; Hoki *et al.*, 1988; Wilkes and Addai, 1988; Tingxi and Zengrui, 1989; Shinners *et al.*, 1990, 1992; Salokhe *et al.*, 1994 and Kosutic *et al.*, 1995). The analysis of variance for fuel consumption showed that there was a significant difference among the 15 treatments as well as among the 5 tools. The forward velocities seemed to be ineffective along with their interaction with the tools. This was reflected in the regression analysis by the non-significant values of the regression coefficients and by the insignificant correlations.

Effect of forward velocity on fuel consumption - The first-order interaction between the tools and different levels of forward velocity on fuel consumption for the active-passive tools are explained in **Table 4**. It was observed that the forward

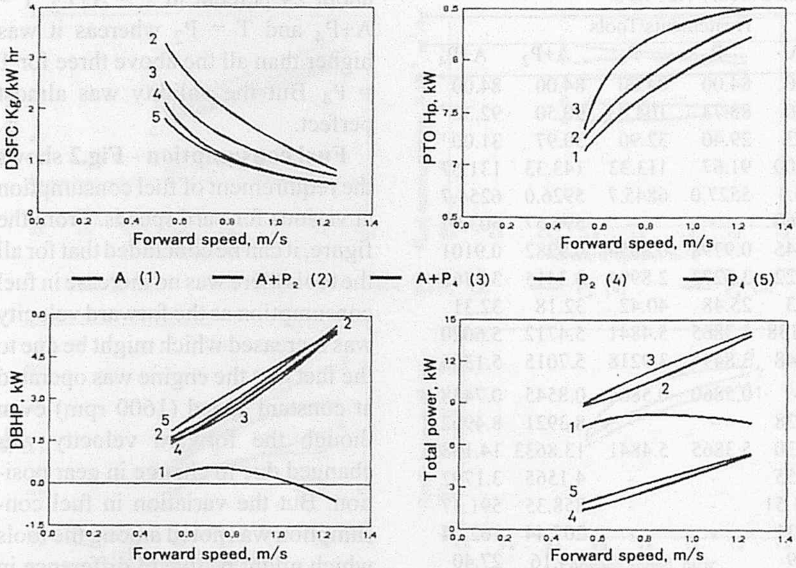

Fig. 3 Power requirement at different forward speeds.

velocity had no significant effect on fuel consumption for all the active-passive tools. The linear regression equations fitted between fuel consumption (Y) and forward velocity (X_1)are:

i. For T = A, $Y = 4.563 - 01^{NS} X_1$ and $R^2 = 0.08^{NS}$

Both the correlation and regression were insignificant. There was no association between forward velocity and fuel consumption, i.e., regardless of the forward velocity as the fuel consumption was constant as follows:

ii. For $T = P_2$, $Y = 2.687 + 0.4^{*}X_1$ and $R^2 = 0.85^{**}$

iii.For $T = P_4$, $Y = 3.477 - 0.2^{**}X_1$ and $R^2 = 0.93^{**}$

iv.For $T = A+P_2$, $Y = 5.118 - 0.4^{**}X_1$ and $R^2 = 0.95^{**}$

v. For $T = A+P_4$, $Y = 3.884 + 0.3^{**}X_1$ and $R^2 = 0.995^{**}$

As compared to draft and slip, the rate of change was marginal. This was in agreement with the result conveyed by the analysis of variance.

Torque - The torque required to operate the rotor is shown in **Fig.2**. The torque required to operate the active tool at low, first gear was 507.6 N m which increased by 15 percent at low, third gear. When the passive tool was combined, the torque required increased and was high for $A+P_4$ than $A+P_2$ which might be due to the fact that the increased power demanded when active and passive tools were combined. The analysis of variance shows that there was a significant difference among all the treatments and among the forward velocities only.

Effect of forward velocity on torque - From the first-order interaction between the tools and different levels of forward velocity on torque, it was inferred that the torque was not significantly influenced by the tools at different levels of forward velocity. The linear regression equations fitted between torque (Y) and forward velocity (X_1) are as follows:

i. For T = A, $Y = 45.689 + 10.3^{**}X_1$ and $R^2 = 0.98^{**}$

ii. For $T = A+P_2$, $Y = 46.682 + 10.6^{**}X_1$ and $R^2 = 0.96^{*}$

iii.For $T = A+P_4$, $Y = 48.279 + 10.13^{*}X_1$ and $R^2 = 0.83^{**}$

A look at the regression equations shows that the explanatory power was high in all the three cases. One peculiarity was that the intercept values as well as the regression coefficients were almost identical, i.e., the three regression equations were identical. Which the F test confirms:

Drawbar specific fuel consumption (DSFC) - The effect of forward velocity on drawbar specific fuel consumption (DSFC) is shown in **Fig.3**. The DSFC decreased as the forward velocity was increased for all the tools but the rate of decrease was less beyond 8 m/s. At this velocity, the DSFC was 28 percent less for P_4 as compared to $A+P_4$. Among the tools, P_4 demanded lesser DSFC consumption which might be due to more drawbar power required to operate P_4. In comparing passive and active-passive tools, the DSFC was less for passive tool indicating that the drawbar power required for active-passive tools was less than that of the passive tool which might be due to the influence of negative draft when active and passive tools were combined.

Drawbar horse power (DBHP) - The relationship between DBHP and forward velocity is shown in **Fig.3**. For the active tool (A), the DBHP required decreased as forward velocity was increased beyond 0.7 m/s and it reached zero at 1.03 m/s. At this forward velocity, for $A+P_4$, the minimum DBHP required was 4.2 and the maximum DBHP required was 4.6 for P_4. For all the other tools, the DBHP required increased steadily as forward velocity was increased (Hendrick and Gill, 1971c; Hoki *et al.*, 1988 and Salokhe *et al.*, 1994). At all levels of forward velocity, the DBHP of $A+P_4$ was less as compared to P_4 (Chamen *et al.*, 1979; Hendrick, 1980; Nagaiyan, 1983; Kumar and Manian, 1986; Araya *et al.*, 1987; Hoki *et al.*, 1988; Wilkes and Addai, 1988; Tingxi and Zengrui, 1989; Shinners *et al.*, 1990, 1992; Salokhe *et al.*, 1994 and Kosutic *et al.*, 1995). This clearly shows that the negative draft produced by the active tool was well utilized and hence the reduction of DBHP.

PTO horse power - The horse power supplied by the PTO to operate the active tools for different combinations is presented in **Fig.3**. The power required to operate the active

Table 5. Percent Variation in Power

Tool	Variation in power (%)		
	Low first gear	Low second gear	Low third gear
A+P_2	(+) 0.30	(-) 5.27	(+) 6.64
A+P_4	(-) 2.91	(-) 3.90	(+) 8.09

tools was greater when combined with the passive tools. Since the depth of the active tool was constant, the increased power demanded through PTO might be supplied to the passive tools in the form of negative draft (Hoki *et al.*, 1988). When this negative draft was not utilized by combining the passive tools, this might be detrimental to the power train system of the tractor. The rate of increase in power required was less for A+P_4 when the forward velocity was increased beyond 0.8 m/s. At this forward velocity, the PTO power required was 2.2 percent more for A+P_2 and 6.95 percent more for A+P_4 as compared to A alone.

Total power - The total power required to operate the active, passive and active-passive tools are presented in **Fig.3**. The total power required was high for A+P_2 and A+P_4 since for either active or passive tools alone, either rotary power or draft power was required. As the forward speed was increased, the total power also increased steadily for the passive or combination of active-passive tools (Hendrick and Gill, 1971; Hoki *et al.*, 1988 and Salokhe *et al.*, 1994). But for the active tool alone, it was almost constant irrespective of the forward velocity. The measured values of total power for the active-passive tools deviated either on the plus side or on the negative side of the arithmetic total power requirement for active and passive tool in **Table 5**.

As seen from the above table, the variation in positive side was up to 8.09 percent while in the negative side it was only 2.91 percent which might be due to the role played by the negative draft in addition to measurement error.

Comparative performance and cost - The energy required to operate the different implements and active-passive tillage tools are:

Mould board plough, MJ/ha=1387.9
Cultivator, MJ/ha = 226.7
Disc harrow, MJ/ha = 374.4
Mould board plough + cultivator, MJ/ha = 1614.6
Mould board plough + cultivator + disc harrow, MJ/ha = 1989.0
Active - passive tillage tools, MJ/ha = 569.9

The energy required, time required and cost of operation by using various combinations of implements are presented in **Table 6**. Different implement combinations were selected to obtain uniform soil tilth by assessing the bulk density. It was found that the bulk density was in the close range of 1.49, 1.38 and 1.26 g/cc for T_1, T_2 and T_3 respectively.

As seen from the table the energy required was higher for mould board plough + cultivator + disc harrow combination (1989 MJ) while it was lowest for active passive tool. The saving in energy was in T_3 183.3 and 249 percent as compared to treatments T_1 and T_2 respectively. Similarly the time required to cover an unit area with active-passive tools was very less, and higher for other two treatments by 161.3 and 232.3 percent for T_1 and T_2 respectively. The cost of operation for the active-passive tillage tools was 19.13 $/ha whereas it was 50.19 and 64.47 Rs/ha for T_1 and T_2 respectively. The cost of operation of active-passive tillage machine was drastically reduced besides reducing the chances of forming hard pan due to reduced traffic of implement power system for performing almost the same quality of work.

Table 6. Cost and Energy Requirement

	Implement combination	Energy required/ha (MJ)	Time required/ha (hr)	Cost of operation/ha ($)
T_1	Mould board + cultivator	1614.6	8.1	50.59
T_2	Mould board + cultivator + disc harrow	1989.0	10.3	64.47
T_3	Active-passive tillage tool	569.9	3.1	19.13

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Status of Power Tiller Use in Bihar - A Case Study in Nalanda District

by

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Abstract

The important task before the agricultural engineers and extension workers is to develop a method to improve tractor and power tiller utilization pattern which varies according to farm size. The power tiller population has increased rapidly in Bihar in recent years. The present study was taken up with a view to gathering information regarding power tiller utilization pattern, cost of operation, economics of use and feasibility for the purchase of power tiller at the farmers' level. The study was confined to Nalanda district of Bihar state, where the maximum numbers of power tiller exist. A random selection of 25 power tiller owners was made and a comprehensive information was obtained through a specific survey performance. The study reveals that the power tillers are mainly used for ploughing operation only among all the categories of farmers and its effective use was observed in vegetable cultivation. With the availability of bank loan and subsidy facility, the popularization of the power the tiller has increased to some extent. However, farmers explained some great difficulty in getting bank loan and Government subsidy. Thus, there is a need to simplify the system to increase the popularization of power tiller and other matching implements. The study also reveals that farmers use power tillers on their own farm only. There was no hiring demand for power tiller in the study area.

Introduction

Bihar with 17.3 m ha geographical area in a thickly populated state sharing 10.21% of country's population and 5.29% in area. More than 82% of the population depends mainly upon agriculture which contributes about 50% of net state production. The net cultivable area in the state is only 10.90 m ha, which is about 62.72% of total geographical area. The growing demands of the increasing population has now put a great question mark for their foods and fibers. At present, the State produces about 13.5 million tonne food grain against a total demand of to 17.7 million tonne by the 2000. It is very difficult to increase the cultivable area. Instead it is the adoption of intensive cultivation through mechanized farming system. Thus, it is necessary to perform various farm operations by mechanical means such as tractors, power tillers and stationary engines along with their matching equipment.

The important task before the agricultural engineers and extension workers is to establish a method of utilization of tractor or power tiller according to farm size. A study carried out by the National Council of Applied Economic Research (NCAER) in 1980 reveal that large farms have higher utilization of power source than small farms. To modernize the various agricultural operations, farm mechanization is essential. The process of farm mechanization includes the use of a large number of machines on the farm.

It has been observed that about 71.87% of net sown area in the State remains under single crop cultivation system in a year. Also, the yield of these crops are very low despite being endowed with adequate natural resources like water, productive soil and climate. The use of higher yielding variety seeds, fertilizers, insecticides, pesticides, etc. has reached its saturation level. The alternative left for the farmers is to use improved farm implements. This will enable the farmers to obtain at least three crops in a year with their high productivity.

Present Status

The use of improved implements in the State is very poor. It is estimated that the state has about 40,000 tractors, 3,000 power tillers and over 2 lakh stationary engines. Including the animal power and human power available in the state which is about 19 lakh-hp and 7.37 lakh-hp, respectively, the total power availability comes out to be only 0.6 hp/ha, whereas in other states like Punjab and Hariyana it varies from 4 hp/ha to 6 hp/ha. This may be one of the main reasons for getting low yield in the State. The sufficient availability of power will also facilitate the proper crop management. Hence, to increase the productivity of various crops and total production, it has now become very essential to increase the total power input to agriculture sector.

Looking at the land holding pattern in the State as shown in **Table 1**, it may be stated that about 88% of the farmers hold below 2 ha land and belongs to the category of small and medium size. Keeping tractor or any other big machinery is not economical for them. However, they can easily accept the small size power source like power tiller and its matching implements.

Scope of Power Tiller Technology

It is obvious from **Table 1** that a large section of farmers belong to the category of small and medium size holdings. The lands are utilized either for growing crops like cereal, pulses and oilseed or for orchard and vegetable production. About 2.29% of the total cultivable area is planted fruit trees. It is estimated that the State produces about 2.3 million tonne of fruits contributing to 10.05% of total fruit production at the national level. The effective interculturing operation and proper soil management will further increase the productivity of fruit trees. At present most of the field operation is done by human labour which is very tiring and time consuming. The use of bullocks or tractors for interculturing operation under the tree is very tedious.

Table 1. Land Holding Pattern in Bihar

Size of holding (ha)	No. of holding (million)	Percent of total no. of holding	Total area (m ha)	Percent of total area
0 – 2	10.303	88.00	5.172	47.46
2 – 4	0.951	8.11	2.593	23.80
4 – 10	0.404	3.45	2.293	21.05
10 and above	0.052	0.44	0.837	7.70
Total	11.710	100.00	10.897	100.00

Source: Bihar Through Figures 1990-91.

Hence, power tiller is the only appropriate source of power to perform all kinds of works like interculturing, spraying of insecticides etc. The State has a very wide scope for the use of power tiller in the orchards of about 140,147 ha, banana (20,483 ha), guava (20,353 ha), litchi (15,453 ha), citrus (14,159 ha) etc.

Extent of Adoption

The State is not new in adopting of power tiller technology. The power tiller population has increased rapidly in Bihar in recent years. However, a systematic study has not been carried out in the State regarding power tiller utilization pattern and their economics of use. The present study was, therefore, undertaken with a view to visualizing the various constraints in the adoption of power tiller technology and their feasibility of purchase at by small-and medium-farmers.

Methodology

The study was carried out in an alluvial plain zones-III of south Bihar in Nalanda district. During the selection of the study areas, the ecological conditions of the district, availability of power tiller technology and its use were duly considered. It was not possible to consult all the power tiller owners in the district, hence a random sampling of 25 power tiller owners were done. A comprehensive survey questionnaire was thus prepared and information was gathered from the farmers. The questionnaire was designed to obtain data related to power tiller utilization pattern, annual use of power tiller, age of power tillers, farm size and total cost involved in operation of power tillers. The information were collected regarding various operations such as tillage, sowing, harvesting, threshing and transportation. Data were also collected regarding the use of power tiller on the farmers' own field as well as for custom hiring works. The cost of operation of power tiller was determined considering depreciation, interest, shelter, taxes, insurance, fuel and lubricants, labour, repair and maintenance charge.

Results and Discussion

Status of Farmers and Power Tiller Utilization Pattern

Status of power tiller owners- The farmer with less than 6 ha and more than 2.5 ha of land were grouped under semi-medium farmer (SMF), whereas the farmer with holding size between 6 and 10 ha was categorized as medium farmer (MF) and those having 10 ha and above were grouped under the category of large farmer (LF).

As obvious from **Table 2**, out of 25 farmers, 20 farmers belong to medium category, 2 farmers belong to semi medium category and 3 of them to the large farmers category, accounting for 80% in the medium size farmers, 8% semi-medium size and 12% in the large size farmers category. The 14 farmers out of 20 medium size use power tillers as well as bullocks both accounting for 70% of the total medium size farmers. It is also evident that all the large category farmer use power tiller with bullocks and none of the semi-medium category farmer use power tiller with bullocks.

Purchasing capacity of the farmer- The actual situation of new power tiller owners is shown in **Table 3** showing that of 20 farmers of medium category, only 13 purchased new power tiller contribut-

Table 2. Status of Power Tiller Owners

Category	Size of Farm (ha)	Holding with power tiller, No.	Holding with power tiller, (%)	Holding with P.T without bullocks No., (%)	Holding with P.T. as well as bullocks No., (%)
SMF	< 6	2	8	2 (100)	0 (0)
MF	6 to 10	20	80	6 (30)	14 (70)
LF	> 10	3	12	0 (0)	3 (100)

Table 3. Purchasing Capacity of Farmers

Category	Size of Farm (ha)	Holding with power tiller, No.	New purchased power tiller No.	Old purchased power tiller No.	New purchased power tiller, (%)
SMF	< 6	2	1	1	50
MF	6 to 10	20	13	07	65
LF	> 10	3	3	0	100

Table 4. Annual Use of Power Tiller at Farmer's Level

Category	Size of farms (ha)	Holding with power tiller, No.	Total areas (ha)	Total annual use (h)	Average annual use (h)	Annual use (h/ha)
SMF	< 6	0.2	6.00	1000	500	166.60
MF	6 to 10	20	132.75	16600	880	125.05
LF	> 10	03	32.00	2900.00	966.60	90.63

Table 5. Cost per hour and Cost per hectare at Various Level of Annual Use

Annual use (h)	Holding with power tiller, No.	Total annual use (h)	R&M cost per power tillers (Rs)	Cost of use (Rs/h)	Cost of use for plowing operation (Rs/ha)
400-600	2	1000	75350	75.35	627.66
600-800	12	9150	525022.5	57.40	477.96
800-1000	11	10350	524202.5	50.64	421.83

Table 6. Cost of Use of Power Tillers at Different Ages

Age of power tiller (Year)	Holding with power tiller, No.	Average annual use (h)	R & M Cost per power tiller (Rs)	Cost of use (Rs/10h)	Cost of use (Rs/ha)
< 2	05	810	5400	551.10	459.10
2-5	10	650	10400	684.50	570.25
5-8	02	900	14800	608.16	506.60
> 8	08	812.5	18600	689.60	574.46

ing about 65% of total medium category farmers. Similarly, only one farmer in the category of semi-medium size purchased new power tiller, which was 50% of total in that category. All the farmers of large size category purchased new power tillers. This indicates that the large farmers, who are capable of purchasing new power tillers, prefer to go for purchase of new one.

Utilization pattern of power tiller - The average annual use of power tillers is 500 hours in the case of semi-medium category farmers, 880 hours in the case of medium category farmers and 966.6 hours for large size farmers. Thus the large-sized farmers have the highest annual use of 966.6 hours for large size farmers. Thus the large size farmers has the highest annual use of 966.6 hours with power tillers. On the other hand, annual use of power tillers per hectare holding was maximum with the semi-medium category of farmers as 166.6 hours. It was only 90.63 hour per hectare for large category farmers and 125.05 hours per hectare for the medium category farmers. Thus, the annual use of power tillers increases with the increase in farm size. Hence, it may be interpreted that per hectare use of power tiller was comparatively high on small farms and low on big farms.

Hiring Demand

Hiring demand for power tiller was shown in all the cases, but none of the farmers accepted to have hiring demand for power tillers for any operation. The main reason behind this was its high operational cost of use as compared to tractor.

Operating Cost of Power Tiller

The operating cost of power tillers was determined based on its annual use, age and farm size for agricultural use for three different categories as 400-600 hours, 600-800 and 800-1000 hours (**Table 5**). It is evident from the table that the total operating cost per hour varies from Rs.50.64 to Rs.75.35 for annual use of 1000 hrs to 400 hrs, respectively. The cost of operations decreases with an increase in annual use of power tillers. The cost of use varied from Rs.627.66 per ha to Rs.421.85 per ha for annual use of 400 hours to 1000 hours, respectively.

The operating cost of power tillers was influenced by their age as shown in **Table 6**. The total operating cost was estimated at Rs.551.10 for 10 hours of use of power tillers up to 2-year age group. This increased to Rs.689.60 for 10 hours of use in the category of more than 8-year age group of power tiller. The annual repair and maintenance cost of power tillers also increased from Rs.5400 to Rs.18600 with the increase in the age of power tillers. The cost per hour use of power tiller in the age group of 5 to 8 years is less than the age group of 2 to 5 years due to fact that the total annual use for one power tiller is 900 hours in the first case whereas it was 650 hours only in second case.

As repair and maintenance cost per power tiller increased, the cost of use per hour also increased except in the case of age group of 5 to 8 years. In the beginning, the maintenance cost was less but increased as the machine aged and operating cost.

Table 7. Cost of Power Tiller Use for Different Farm Sizes

Category	Holding size (ha)	No. of holding with power tiller	Total annual use (h)	Total annual cost of use (Rs)	Cost of use (Rs/h)	Cost of use (Rs/ha)
SMF	< 6	02	1000	75350	75.35	627.66
MF	6 to 10	20	16600	907290	54.56	455.28
LF	> 10	03	2900	145435	50.15	417.75

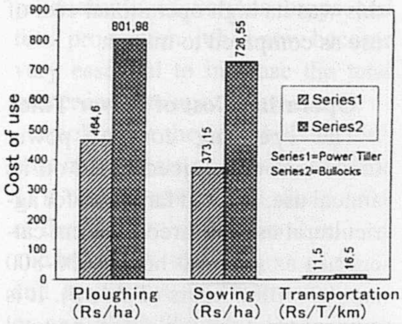

Fig.1 Comparative cost of use of power tillers and bullocks.

The effect of farm size and operating cost of power tillers is shown in **Table** 7. It will be shown that the unit cost of use of power tiller decreases with the increase in farm size. The cost of use per hour was Rs.75.35 for farm size of below 6 ha. It decreased to Rs.50.15 as the farm size increased above 10 ha due to low use of power tiller on holding size below 6 ha than that of above 10 ha.

Comparative Costs

A comparative analysis of cost of use of power tiller as well as a pair of bullocks was carried out to determine their economics of use (**Fig.** 1). The cost of plowing, sowing and transportation with a pair of bullocks amounted to Rs.801.98 per ha Rs 726.55 per ha and Rs.16.5 per tonne per km, respectively. Whereas with the use of power tiller the cost was to only Rs.464.60 per ha, Rs.373.15 per ha and Rs.11.5 per tonne per km, respectively.

Thus, the use of power tiller was 42.07% more economical for plowing; 48.68% for sowing; and 50% for transportation. Moreover the power tiller can also perform some other operations like harvesting, threshing and water pumping which are practically impossible with the use of bullocks.

Farmer's Reactions in Adoption of Power Tiller Technology

As viewed by many farmers, power tillers are certainly useful for various farm operations. In addition to dry and wet ploughing of field, it also performs stationary work like water pumping and threshing. Farmers were of the opinion that the following advantages in the use of power tiller over the traditional use bullocks were desirable.

1. Saving of *Bhusa* and one manpower required to upkeep a pair of bullocks;
2. Timeliness in completion of most of the agricultural operations.
3. The initial price of power tillers and its matching implements are not within easy reach of small and medium farmers.
4. The subsidy should be made available to all the farmers in every district, whoever desires to purchase the power tiller.
5. The bank loans should be available to farmers at special low interest rates.
6. Ready availability of original spare parts through dealer's network.
7. A trained and skilled mechanic from the manufacturing company should be deputed in each district in order to enable the farmers to complete repair work without much delay during peak demand of crop season.
8. The farmers should be encouraged to obtain training for repair and maintenance of power tillers and its matching implements to develop confidence among the farmers for effective use power tillers.

Conclusion

1. The use of power tillers was highest in the category of semi-medium sized farmers for ploughing;
2. Availability of bank loan and Government subsidy should be simplified to enhance the popularization of power tillers among the farmers;
3. The availability of repair facility within a distance of 2-10 km and genuine spare parts should enable the farmers to keep full faith on the power tiller;
4. There is a great need for training and demonstration on power tillers and their various matching equipment for farmers; and
5. The use of power tiller was 42.07% more beneficial for ploughing, 48.68% for sowing and 50% for transportation work. Moreover, timely completion of various farm operations was an added advantage over the traditional bullock power.

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Development And Evaluation of a Till Planter for Cotton

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Abstract

A tractor-drawn till-planter for cotton was developed which combined seed bed preparation operations along with planting. The unit consisted of six cultivator tynes with shovels, a three bottom ridger and a cup feed type planter to perform tilling, forming ridges and furrows and planting on one side of the ridges in a single pass. The unit was field evaluated for its performance. The forward speed of operation was optimized as 1.40 m/s, considering the desired seed rate and seed spacing. The average draft and fuel consumption of the unit was 2300 N and 3.82×10^{-3} m^3/hr, respectively. The field capacity of the unit was 0.81 ha/hr with field efficiency of 71.43 percent. The till-planter registered less deviation (0.93 percent) from recommend spacing, planted the recommended number of seeds in majority of the hills and resulted in more uniform depth of seed placement when compared to conventional method. The cost of the till-planter was Rs 22,500. The till-planter resulted in 23.65, 90.09 and 18.25 percent saving in cost, time, and energy, respectively, when compared to conventional method.

Introduction

Cotton plays an important role in India's agrarian and industrial economy. India ranks first in the world in area planted to cotton (7.86 million ha). Cotton accounts for around 70 percent of total fiber consumption in the textile sector which accounts for nearly 20 percent of India's industrial production and 28 percent of exports. Cotton production in the country is spread over nine states in three cotton growing zones, accounting for nearly the entire area and total production in the country. The term till planting is generally agreed to be a practice that eliminates seed bed preparation as a separate operation or combines it with planting operation. Rational methods of tillage are directed at creating optimal conditions for plant growth and development at which the soil prepared for sowing has the necessary soil conditions for ensuring moisture conservation, good contact of seed with soil, uniform germination, good plant development and high yields. Efficient use of costly input by proper and timely operation can be achieved by appropriate adoption of machinery. Considering these new tendencies of tillage for row crop production, a till-planter for sowing irrigated cotton was developed.

Review of Literature

Bolton and Booster (1981) developed a strip-till planting system for cereal production in which tilling the planting strips, application of fertilizers and herbicides and seeding can be accomplished simultaneously. Singh et al. (1985) developed a two-row ridge planter for planting winter maize and evaluated in the field over an area of 0.4 ha. Development and evaluation of a tractor-drawn ridger-seeder for maize and sorghum was also reported (Anon. 1986). A savings of 91 percent in sowing time and 42.0 man hour per ha was obtained using the implement.

Rodriguez and Soto (1989) developed a machinery that carried out four simultaneous operations, namely, soil loosening, soil levelling, drilling and fertilizer application. Field evaluation of the unit showed that savings of 57, 50 and 40 percent were attained for total operating cost, fuel and labour, respectively. Dmitriev et al. (1995) discussed the advantages of sowing maize on ridges and presented a tractor drawn ridger cultivator for sowing maize. Kosutic et al. (1995) reported that the wheat and rape seed production tillage system using a single pass of rotary cultivator with integrated drill achieved lowest energy and labour requirements.

Materials and Methods

The crop parameters influenced the development of the till-planter for cotton are row spacing (0.45 to 1.2m), plant-to-plant spacing (0.30 to 0.60m), depth of planting (30 mm), number of seeds per hill (1 to 2), quantity of seeds (2.5 to 7.5 kg/ha) and the normal germination percentage of seed (65 - 80). The seed properties considered are the bulk density which influence the volume requirement of seed hopper and degree of packing, thousand grain weight which is an indicator of size of grain and influenced the seed rate and the volume of cotton seeds.

Considering the factors discussed above, a tractor mounted till planter was developed with the following functional component: The cultivator commonly available among farmers as an attachment to tractor was used as the tilling mechanism. In the commonly available cultivators, nine cultivator tynes are staggered in two rows. In till planter six tynes were provided in the front row of a cultivator for tilling. Ridges and furrows can be effectively and economically formed using tractor drawn ridger and planting can be done simultaneously by incorporating the planting mechanism with the ridger. Hence, three ridger-bottoms were selected for the formation of ridges and furrows. These ridger-

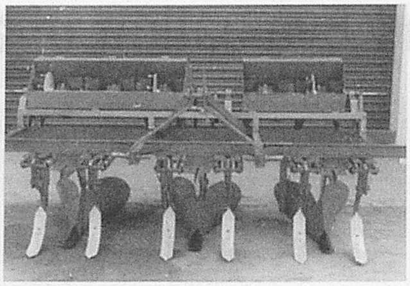

Fig.1 Till planter for cotton.

Fig.2 Till planter in operation.

bottoms were mounted, such that each one was placed in between two cultivator tynes (**Fig. 1**). The planting mechanism consisted of a seed hopper with two compartments: one for seed storage and another for seed metering. The seed metering mechanism was of cup feed type as it was found effective for various types of seeds. The cup feed mechanism also has the advantage of minimum seed damage compared to other common types of seed metering devices. A ground wheel with spikes was provided for driving the seed metering device. A funnel like structure was provided in the seed metering compartment for guiding the seeds metered to the other part of the seed placement device. On the lower side of the seed funnel a transparent flexible PVC hose was connected to the final placement device.

The soil thrown by the wings of the ridgers formed the ridges (**Fig. 2**) and provisions were made to place the seeds while the formation of ridges itself and hence the need for separate furrow openers and furrow closers were eliminated. A mild steel tube fixed on one side of the ridger bottom was used for placement of seeds. No separate device was provided for covering the dropped seeds, as the soil thrown by the wings of the ridgers itself covered the dropped seeds. Depending on the type of travel pattern, to mark the next row over which the next pass of unit has to be started A row marker was provided on either side of the unit.

The calibration of the unit was done in the laboratory with a seed drill test rig to obtain the seed rate at various speeds of the rotor, corresponding to the forward speed of the unit. To find the uniformity of seed distribution, tests were conducted in a soil bin with a loading car, operated at four different forward speeds, viz., 0.36, 0.61, 1.06, and 1.53 m/s. The spacing between the seeds placed on the sand and the number of seeds dropped at each point were noted in a length of 15 m. Tests were conducted in sandy loam soil at the Tamil Nadu Agricultural University campus for evaluating the performance of the unit. Cotton variety LRA 5166 was planted in an area of 0.4 ha using the unit. Before operating the unit, the field was prepared by disking once and ploughing with cultivator once. A control plot of 0.4 ha was also planted to the same variety for comparing the performance of the unit with conventional method. In the control plot, cotton seeds were manually dibbled on ridges formed by tractor drawn ridger. The operations performed in the control plot prior to ridge formation include disking once and ploughing with cultivator twice. The time required to cover the area, the time lost in turning, average travel speed, actual quantity of seeds used were measured during the operation.

The draft of the unit was measured by the rolling method as per RNAM test code. For measuring the fuel consumption, a fuel consumption meter was used. The number of revolutions of the ground wheel of the planter for a distance of 20 m covered by the unit was recorded for calculating

Table 1. Seed Spacing at Different Forward Speeds of Operation

Forward speed, m/sec	Seed spacing, mm (Mean of all rows)	SD	CV	Deviation from the recommended, percent
0.36	0.3150	3.58	0.113	5.00
0.61	0.3206	4.51	0.141	6.87
1.06	0.3109	3.01	0.097	3.63
1.53	0.3039	2.28	0.075	1.30

the wheel slip. The field capacity and field efficiency of the unit was found by operating the unit in an area of 0.4 ha.

The spacing between the plants and the number of plants per hill for a known length was measured to analyze the uniformity of plant spacing. The coefficient of variation and standard deviation were calculated. The percent missing, single plant and multiples per hill were also found. The values obtained for the till-planter and conventional method were compared. The depth of seed placement was measured by removing the plant from soil. The plant population was assessed by counting the number of plants in a known area. The readings were recorded from randomly selected six different locations in the field. A germination test was conducted to study the actual germination of LRA 5166 cotton seeds. The cost of operation of the till-planter was determined as per RNAM test codes. The cost, time and energy requirement of the till-planter was compared with the conventional method.

Results And Discussion

Laboratory Calibration of Till-planter

The relationship between the peripheral velocity of cup and seed rate in different rows is shown in **Fig. 3**. From the figure, it is evident that there was not much variation in the seed rate obtained in all the three rows. It is also observed at all peripheral velocity of the cup that the variation from the recommended seed rate of 9 kg/ha was marginal. The minimum variation from the recommended rate was obtained for a peripheral velocity of 0.40 m/s. Hence for the desired seed rate, the peripheral velocity of the cup should not be more than 0.40 m/s. The seed rates in different rows at various forward speed are shown in **Fig. 4**. From the figure, it will be shown that the required seed rate of 9 kg/ha in all the three rows was obtained at a forward speed of 1.416 m/s. At all the forward speeds, the seed rate obtained in three rows did not show much variation. The standard deviation (SD), coefficient of variation (CV) and percent deviation from the recommended spacing at different forward speeds of operation are shown in **Table 1**. It is observed from the table that at all the selected forward speeds, the average spacing obtained was slightly greater than the recommended spacing of 0.30 m. This may be due to the light weight of seed and the variation in the time taken by the seed to reach the final placement point form the metered location. The minimum value of

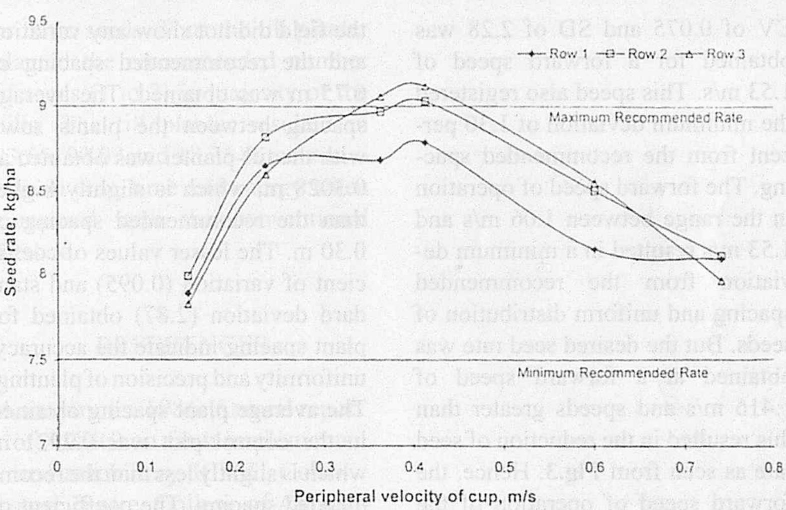

Fig.3 Relationship between peripheral velocity of cup and seed rate in different rows.

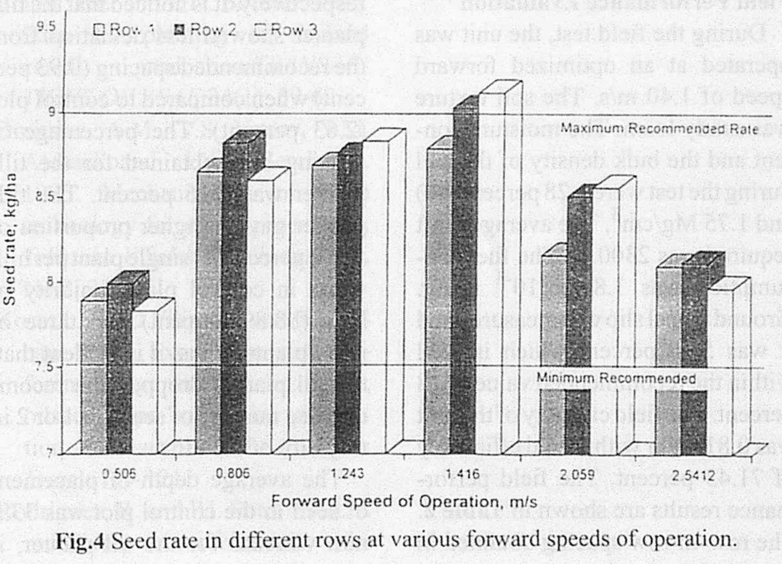

Fig.4 Seed rate in different rows at various forward speeds of operation.

Table 2. Field Performance Results

Particulars	Till planter	Control
Seed spacing, m	0.3028	0.2921
Standard deviation	2.870	3.7040
Coefficient of variation	0.0950	0.1154
Deviation from recommended spacing,%	0.93	2.63
Depth of seed placement, mm	30.7500	33.5
Standard deviation	0.2006	0.5428
Coefficient of variation	0.0652	0.1567
Deviation from recommended spacing,%	2.5	11.67
Missing hills, percent	8.16	0.00
Percentage of single plant	51.02	4.76
Percentage of double plants	36.73	6.35
Percentage of triple or more plants	4.08	88.89

Table 3. Abstract of Appraisal of Cost, Time and Energy

Method	Cost (Rs/ha)	Time (hr/ha)	Energy (MJ/ha)	Percent saving in		
				Cost	Time	Energy
Control	2649.15	89.19	1718.54	-	-	-
Till planter	2022.60	8.090	1404.96	23.65	90.09	18.25

CV of 0.075 and SD of 2.28 was obtained for a forward speed of 1.53 m/s. This speed also registered the minimum deviation of 1.30 percent from the recommended spacing. The forward speed of operation in the range between 1.06 m/s and 1.53 m/s resulted in a minimum deviation from the recommended spacing and uniform distribution of seeds. But the desired seed rate was obtained at a forward speed of 1.416 m/s and speeds greater than this resulted in the reduction of seed rate as seen from **Fig.3**. Hence, the forward speed of operation of the unit was optimized as 1.40 m/s.

Field Performance Evaluation

During the field test, the unit was operated at an optimized forward speed of 1.40 m/s. The soil texture was sandy loam. The moisture content and the bulk density of the soil during the test were 3.28 percent (db) and 1.75 Mg/cm^3. The average draft required was 2300 N. The fuel consumption was 3.83 x 10^{-3} m^3/hr. Ground wheel slip was measured and it was 5.75 percent which is well within the recommended value of 18 percent. The field capacity of the unit was 0.81 ha/hr with a field efficiency of 71.43 percent. The field performance results are shown in **Table 2**. The row-to-row spacing obtained in the field did not show any variation and the recommended spacing of 0.75 m was obtained. The average spacing between the plants sown with the till-planter was obtained as 0.3028 m, which is slightly higher than the recommended spacing of 0.30 m. The lesser values of coefficient of variation (0.095) and standard deviation (2.87) obtained for plant spacing indicate the accuracy, uniformity and precision of planting. The average plant spacing obtained in the control plot was 0.2921 m which is slightly less than the recommended spacing. The coefficient of variation and standard deviation in control plot was 0.1154 and 3.704, respectively. It is noticed that the till-planter showed less deviation from the recommended spacing (0.93 percent) when compared to control plot (2.63 percent). The percentage of missing hills obtained for the till-planter was 8.16 percent. The till-planter gave a higher proportion of 51.02 percent for single plant per hill, while in control plant majority of hills (88.89 percent) had three or more plants. Thus, it is evident that, the till planter dropped the recommended number of seeds of 1 or 2 in majority of the hills.

The average depth of placement of seed in the control plot was 33.5 mm whereas for the till-planter, it was 30.75 mm. The standard deviation, coefficient of variation and deviation from the recommended depth were less(0.20, 0.065 and 2.5 percent) for those planted with the till-planter compared with the manual planting (0.543, 0.157 and 11.67 percent). Thus more uniform depth of seed placement was obtained using the till-planter. The plant population in the field planted by the till-planter was 75,556 plants per ha. Considering one plant per hill, the required plant population is 44,445 plants per ha. The plant population obtained was high for the till-planter due to the fact that more than one seed was planted per hill in 40.81 percent of hills, so as to get plants in all the hills. The plant population obtained in the control plot was 106,660 plants per ha. The higher plant population in the control plot was due to planting of three or more than three seeds per hill in majority of the hills (88.89 percent).

The plant population after thinning in the field planted by the till planter was 41,556 plants per ha, which was 6.5 percent less than the recommended plant population. This was due to the missing of certain hills and also due to the fact that the average spacing obtained was slightly greater than the recommended spacing of 0.30 m. In the control plot, the plant population obtained was 50,000 plants per ha, which was 12.5 percent more than the recommended plant population. This may be due to the fact that average spacing obtained in the control plot was less than the standard spacing. The crop stand on the 25th day before thinning and on 46th day after thinning and intercultural operations are shown in **Figs. 5** and **6**. The germination percentage for cotton seed variety LRA 5166 was 72 percent. The abstract of appraisal of cost, time, and energy for the till-planter and conventional method are shown in **Table 3**.

It is observed that the operations with the till-planter resulted in

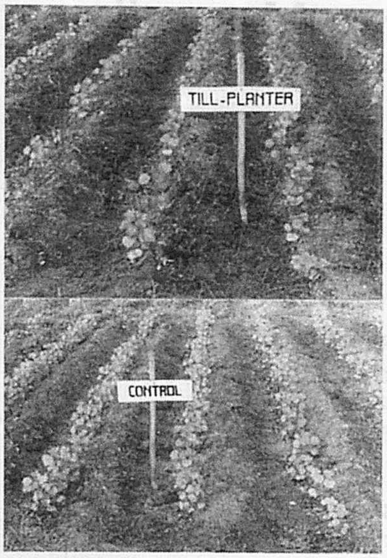

Fig.5 Crop stand on 25th day.

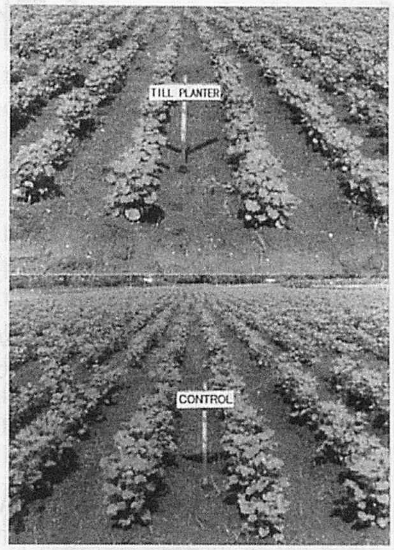

Fig.6 Crop stand on 46th day.

23.65, 90.09 and 18.25 percent savings in cost, time, and energy, respectively, when compared to with those of the conventional method.

Conclusions

Based on the results obtained, the following conclusions were drawn:

No significant variation in seed rate and seed spacing was found in different rows. Considering the seed rate, uniformity of seed distribution and ridge and furrow profile, the forward speed of operation was optimized as 1.4 m/s. The average draft of the unit at the optimized forward speed of operation was 2300 N. The fuel consumption of the unit was 3.82 $\times$ 10^{-3} m^3/hr. The slip of the planter's ground wheel was 5.75 percent. The field capacity of the unit was 0.81 ha/hr with a field efficiency of 71.43 percent. The plant row spacing obtained in the field was 0.75 m. The average plant spacing obtained in the field was 0.3028 m and 0.2921 m for the till-planter and conventional method, respectively. The till-planter planted one seed in majority of the hills (51.02 percent), followed by two seeds per hill (36.73 percent) and in the conventional method 88.89 percent of hills were planted with three or more seeds. Thus the till planter planted the recommended number of seeds (1 to 2) in majority of the hills. The till planter resulted in 23.65, 90.09 and 18.25 percent savings in cost, time and energy when compared with the conventional method.

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Comparative Performances of Three Manually-Operated Pumps

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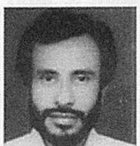

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Bangladesh.

Abstract

Three different manually-operated pumps, namely; BRRI Diaphragm Pump, No. 6 Hand Pump (Reciprocating Pump) and Rower Pump were tested at the Bangladesh Rice Research Institute (BRRI) for comparing their performances. This study shows that BRRI diaphragm pump was the best in respect of cost, capacities, ergonomic characteristics among the pumps up to three-meter head. At places where the lift was more than three meters, the Rower Pump was a better performer.

Introduction

The timely supply of irrigation water, compared to any other inputs favours effectively the production of field crops. Year-round cropping is possible in areas where irrigation water supply is assured and manageable. At present, about 30% of the total cultivable land in the country has some access to irrigation water both by modern and traditional techniques (GOB,1991).

Pumps operated by electric motors or engines are efficient but out of reach of many small farmers due to their high initial and operating costs. The deep and shallow tubewells now used in Bangladesh are becoming expensive and difficult due to high price of spare parts and mechanical problems. The irrigation efficiency of systems has been reported to be below 30% of their total capacity (Baqui, 1980). Moreover, a large number of Bangladeshi farmers have small and fragmented landholdings which also suit manual pumps. Therefore, the manually-operated pumps are becoming increasingly popular to small farmers due to their low cost and ease of operation and maintenance and they can own the equipment individually.

In Bangladesh, where fuel and machinery costs are higher than labour cost and people need not be well trained, the manually-operated pumps can play a major role in small-scale irrigation.

Considering the above facts a few manually-operated pumps have been developed by different organizations in recent years. A comparative study of these pumps can help the buyer to choose the suitable one for his pumping needs. Among these three, hand-operated pumps were selected considering their extent of use and popularity. They were tested for evaluation of their performance.

Materials and Methods

Three pumps were selected and evaluated as mentioned earlier for their performance. A brief description of the pumps are as follows:

BRRI Diaphragm Pump

This model is a reciprocating type of hand-pump made of steel sheets, G.I. pipes and rubber diaphragm (**Fig.1**). It consists of two rectangular chambers (previous model) with handle and levers, fulcrum and two pairs of valves. The chambers are made of steel boxes of 28 cm × 28 cm at the base and 24 cm in height. The inlet manifold is made from 5 cm diameter G.I. pipe, with inclined faces. Inlet and outlet valves are hinged from the adjacent wall of boxes over the inclined faces so that they could be operated

Acknowledgement: The views and interpretations in this paper are those of the authors and should not be attributed to the organizations.

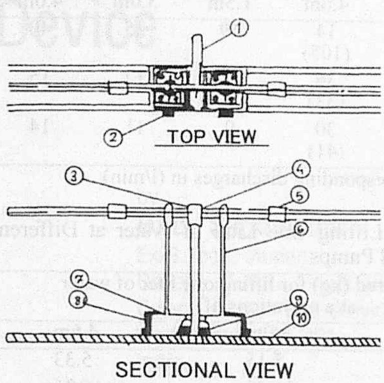

Fig.1 BRRI diaphragm pump.

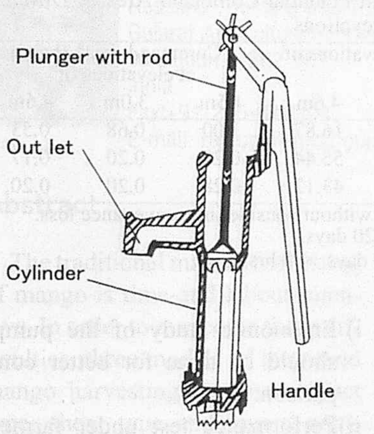

Fig.2 Sectional view of No.6 hand pump.

easily. The rubber diaphragms are discarded inner tubes of tractor or truck wheels and fixed between circular wooden plates. Inlet valves are made from M.S. plates together with rubber flaps. The stroke length of the pump is about 8 cm.

When one end of the handle is pushed downward, the other end moves upward which creates a vacuum in the chamber and thus draws water through a common manifold and a one directional inlet valve into the pump's chamber. Pulling the handle upward causes compression in the diaphragm and forces the water out from the chamber. The directional movement of water is controlled by a set of simple one-directional flap valves on the chamber at inlet and outlet side. Since there are two chambers working simultaneously they lead to two discharges at every stroke.

No. 6 Reciprocating Pump

The reciprocating pumps, sometimes called piston or displacement pumps, function by means of a piston movement which displaces water in a cylinder. No. 6 is a specific type of reciprocating pump (**Fig. 2**). The average weight of the pump is about 30 kg and its height up to head cover is 76 cm (30 in).Its cylinder inside diameter is 11.43 cm (4.5 in) and has a stroke length of 24 cm. The capacity of the pump depends upon the size of the cylinder, the stroke length and the number of strokes.

MCC Rower Pump

The Rower Pump consists of a surge chamber, a cylinder, a plunger and rod with a handle at the free end (**Fig.3**). The pump cylinder is 5.08 cm (2 in) in diameter and 120 cm long and is made of PVC pipe mounted on a hand tubewell at 60 degrees (from horizontal). The surge chamber, plunger and the plunger rod are made of aluminium sheet, cast aluminium and M.S. rod, respectively. A one-directional "foot valve" is located at the lower end of the cylinder body. The surge chamber is oval, about 18 cm in height and is attached to the ground water inlet pipe. The PVC pipe is joined to the tubewell with a branch pipe. The other end of the pump cylinder is open and water discharges through it. The plunger is made of a perforated aluminium disc and a rubberized flap valve seats on it. The surge chamber acts to smoothen the pulsating movement in water, enabling a relatively easy and smooth pumping effort. The possible stroke lengths are about 100 cm. Its principle of operation is identical to the No. 6 reciprocating pump. When the piston is pulled backward the check valve opens and the flap remains closed. The water enters the cylinder through inlet pipe. Then the plunger is pushed forward, the check valve closes and the flap valves open so that water passes through the plunger and is accumulated above it. Thus by creating a continuous backward and forward motion of the piston,water is pumped out of the cylinder simultaneously. Its lifting head up to 7.6 meter (25 feet) is generally recommended though the pump can operate without cavitation up to 8.5 meter (28 feet) head.

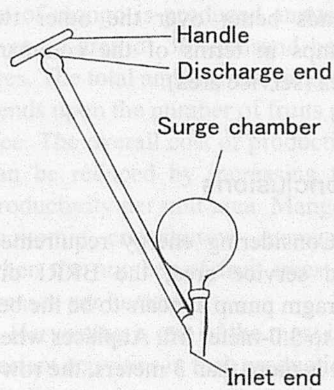

Fig.3 Power pump.

The Test Procedure

All three above mentioned pumps were tested with different arrangements suitable for the individual pump in the pump test bed. The pumps were fitted to the free end of a G.I. pipe which was placed on a platform for discharging water in to a drum. The pumps were tested to check any leakage. The required force was measured by the counterweight and spring balance and strokes were recorded. The time to fill the drum was recorded. The tests were conducted at 1.5, 3.0 and 4.6 meter suction heads.

Results and Discussion

The performance curves for all the pumps are shown in **Figure 4**. All curves indicate inverse relationship between head and discharge which means that with the increase in head the discharge decreased.

The head versus discharge curves (**Fig. 4**) for pumps other than the BRRI diaphragm pump are steeper which may be due to the fact that their discharges did not vary appreciably within the operating heads.This can be attributed to its suction volume which remained constant during operation. In the case of the BRRI diaphragm pump, the curve is more flat, that is, it produced relatively much lower discharges at higher heads compared to the No. 6 and rower pumps which may be due to rubber diaphragm used in the pumps which tend to expand in response to pressure difference due to its elastic properties. Push/pull force requirement for operating the rower and No.6 pumps are almost similar which are even less than half of the same required for BRRI diaphragm pump (**Table 1**). But the input energy required for lifting one litre of water was lowest with the BRRI diaphragm pump and highest in No. 6 pump (**Table 2**).

The number of strokes for lifting a ha-cm of water, i.e., 10,000 m^2 × 0.01 m or 100 m^3 of water at 1.5 m head was the lowest, i.e., 12.154 (8.44 × 60 × 24=12,154) with the BRRI diaphgram pump whereas the corresponding numbers were 1,16,424 in No. 6 pump and 54,332 in the rower pump respectively (**Tables 1** and **3**). That means that the BRRI diaphgram pump needs less muscle movement compared to the other two pumps. The command

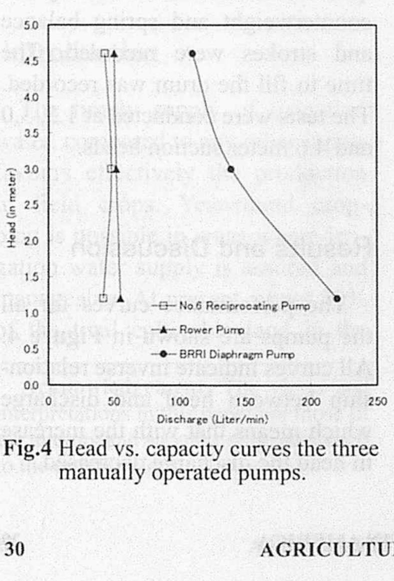

Fig.4 Head vs. capacity curves the three manually operated pumps.

Table 1. Strokes per Minute and Push/pull Force of Different Hand-operated Pumps at Three Different Elevations

Name of pump	Strokes/min. at elevations of			Push/pull force (kg) at elevations of		
	1.5m	3.0m	4.6m	1.5m	3.0m	4.6m
BRRI diaphragm pump	24 (210)	28 (136)	14 (105)	19	25	40
No. 6 reciprocating pump	45 (40)	38 (39)	36 (33)	10	12	15
Rower pump	28 (56)	25 (41)	30 (41)	9	11	14

Note: Numbers within parenthesis are the corresponding discharges in (l/min).

Table 2. Input Energy Required (kg) for Lifting One Litre of Water at Different Heads of Different Hand-operated Pumps

Name of pump	Energy required (kg) for lifting one liter of water at a elevations of		
	1.5m	3.0m	4.6m
BRRI diaphragm pump	2.17	5.15	5.33
No. 6 reciprocating pump	11.25	11.69	16.36
Rower pump	4.50	6.70	10.14

Table 3. Time (hr.) Required per ha-cm and Potential Command Area of Different Hand-operated Pumps at Three Elevations

Name of pump	Hour/ha-cm for elevations of			Command area* (ha) at elevations of		
	1.5m	3.0m	4.6m	1.5m	3.0m	4.6m
BRRI diaphragm pump	8.44	12.93	16.87	1.00	0.68	0.53
No. 6 reciprocating pump	43.12	43.12	55.44	0.20	0.20	0.17
Rower pump	32.34	38.80	43.12	0.28	0.20	0.20

* (a) Assuming 8 hrs. of pumping per day and without considering conveyance loss. Crop: Hyv Rice with a field duration of 120 days.
(b) Operating hrs. assumed to be 960 hrs. (120 days × 8 hrs./day).

area for No.6 and rower pumps were almost similar, whereas it was 2.66 to 5 times higher than in the case of the BRRI diaphragm pump (**Table 3**). However, BRRI diaphragm pump is two-men operated while the other two are one-man operated. Therefore, the two units of No. 6 pumps or Rower pumps can be operated simultaneously instead of operating one diaphragm pump using the same number of labourers. Even then the BRRI diaphragm pump stands better over the other two pumps in terms of the command area (service area).

Conclusions

Considering energy requirement and service area, the BRRI diaphragm pump appears to be the best up to 3.0-meter lift. At places where lift is more than 3 meters, the rower pump performs better. Following are suggested for further studies:

i) Ergonomic study of the pumps should be done for better comparison.
ii) Performance test under farmers management should be carried out to find out actual command area of the pumps, including profitability analysis.
iii) Anthropometric improvement of the diaphragm chamber of BRRI diaphragm pump is suggested in order to increase its capacity.

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Design and Development of a Mango Harvesting Device

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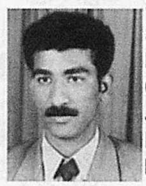
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Abstract

The traditional manual harvesting of mango is time-and labour-intensive. In order to overcome these difficuities, three models of improved mango harvesting devices: impact type, shear type and impact-cum-shear type were developed. Their performance in comparison to the traditional devices was evaluated. The impact type model was the best among the three models, with improved harvesting capacity, cost efficiency and less damage to the fruits. On the other hand, the shear type model could not work due to the fibrous nature of pedicle of the kesar variety of mango. With the use of impact type model, harvesting capacity could be increased by 18% and visible damage to the mango fruit was reduced by 50%.

Introduction

Mango is one of the most important fruits in India. It is grown all over the country. It is cultivated for a reasonably longer part of the year due to the diverse agro-climatic conditions suitable for the production of different varieties of mango. India leads the world in mango production. About 50% of the world production of mango is produced in India and accounts for 35% of India's total fruit production (Shukla *et al.*, 1993). The important varieties of mango grown in India are *Dashehari, Langra, Chause, Bombay green, Himsagar, Fazli, Zardalu, Krishnabhog, Gulkhas, Alphonse, Pairy, Kesar, Rajapuri, Jamadar, Bangalore, Neelam, and Swarnarekha*.

In Gujarat, nearly 320 thousand mt of mango is produced annually over an area of 30 thousand hectares. The total annual fruit yield depends upon the number of fruits per tree. The overall cost of production can be reduced by increasing the productivity per unit area. Mango's economic contribution increases, when the number of fruit trees increases per hectare.

Harvesting is one of the most important activities in fruit production, handling and preservation cycle. In Gujarat, mango harvesting is still carried out by the traditional manual harvesting practice which requires a lot of time and labour. The structure of a mango tree obstructs the harvesting process. Mango fruits do not mature at the same time, a major obstacle for introducing mechanical harvester. Hence, efforts are required to develop suitable mechanical devices / gadgets for plucking the fruits. Attempts were made at the Gujarat Agricultural University to design and develop equipment appropriate for harvesting the mango fruit. Very little research work has been conducted on mango harvesting in the country.

A mango harvesting device was developed on the principle of individual cutting of pedicle by sickle or blade and collecting the fruit in a bag. The device was found suitable for tender and big fruits which are damaged when allowed to fall freely on the ground. Another device known as *'Nutan Nipper'* was developed at Konkan Krishi Vidyapeeth, Dapoli (Maharashtra). It was reported that with this equipment all the fruits could be harvested with petiole avoiding injury to the fruits.

Table 1. Anthropometrical Observations of the Operator

Age, Years	Sex	Height, cm	Weight, kg	Palm size, cm	
				Length	Width
21	M	171.00	62.00	21.00	9.00
20	M	188.00	60.00	20.50	8.00
18	M	155.00	58.00	19.00	7.50
23	M	159.00	62.00	20.00	8.00
21	M	172.00	64.00	20.00	7.00
19	M	175.00	65.00	21.00	8.00
26	M	173.00	70.00	19.50	8.00
28	M	170.00	61.00	21.00	9.50
24	M	165.00	56.00	18.00	8.50
21	M	180.00	70.00	21.50	9.00
Average		170.80	62.80	20.20	8.30

Table 2. Characteristics of Mango Tree (Kesar Variety)

Height, m	Canopy radius, m	Distance between two trees, m
7.0	7.0	11.0
6.0	10.0	10.0
8.0	8.0	11.0
10.0	12.0	11.0
7.0	7.0	11.0
8.5	8.5	12.0
6.5	10.0	12.0
9.0	7.5	10.0
11.0	7.0	12.0
7.5	10.0	11.0
Average 8.5	8.7	11.1

Table 3. Mango Fruit Distribution within the Tree (Kesar variety)

Outside,%	Inside,%	Top,%
50	20	30
57	20	23
59	18	23
70	13	17
58	17	25
58	20	22
62	18	20
60	15	25
71	12	17
64	16	20
Average 60.5	16	22

Table 4. Physical Properties of Mango Fruit (Kesar Variety)

	Length of fruit, cm	Width of fruit, cm	Weight of fruit, g
	9.0	6.5	242
	9.8	6.8	237
	8.3	6.2	161
	7.8	5.9	151
	9.0	6.4	212
	8.4	6.0	163
	9.1	6.4	213
	7.6	5.9	137
	8.6	6.0	199
	9.6	6.3	218
Average	8.84	6.24	193.3

It reduces jerks to the branches and hence no loss by way of fruit drop from the tree. The shaking of the mango tree branches was not required and thus no mechanical injury to the branch of mango tree. The device was reported to be simple and very handy as it could be operated by only one person and harvest 450 to 500 fruits per day. An improved device similar to the *Dapoli* model was designed and developed at the Indian Agricultural Research Institute (IARI), New Delhi. It was a simple, manually operated tool designed to harvest the fruit at different heights and could be used for harvesting mango, guava and citrus fruits. The tool is capable of cutting the pedicle of fruits of 3 to 4 mm diameter from a maximum height of 15 feet. It could harvest *Dashehari* mango at the rate of 38 kg/hr.

Materials and Methods

Before designing the equipment, tree characteristics, fruit locations on the tree, fruit characteristics and and anthropometrical observations were recorded for deciding appropriate size, shape, strength and capacity of different components of the equipment. For the *Kesar* variety of mango, the maximum and minimum height of the tree was 11 m and 6 m, respectively, in the region. The average height was about 8.08 m (**Table 2**). Observations regarding fruit locations on the tree indicated that average percentage of fruits outside, inner side and at the top portion of the tree were 60.9, 16.9 and 22.2%, respectively, (**Table 3**). From these observations, we can say that about 60 to 65% of the fruits can be harvested with about 3-m long equipment from the ground. If the length of the equipment is increased, the weight of the equipment will also go up and that creates problems in harvesting. Therefore, the equipment length was decided at 3 m only. Observations on the mango fruit properties, i.e., length, width and unit weight of fruits as mentioned in **Table 4** were used to decide the ring dimensions and collector capacity. The ring diameter was taken as 30 cm. The circular shape of the ring may not be proper from penetration point of view, hence, an oval shape ring was fabricated for mango harvesting device as it could easily go inside the branches of the tree and catch the fruits to be harvested. The suitable diameter of handle, weight and length of equipment were decided based on the anthropometrical characteristics of the operator. The design details of all three models are shown in **Table 5**.

Three models of mango harvesting device, impact type, shear type and impact-cum-shear type were developed. Each model consists of a handle, oval ring, cutting tool and collector-cum-conveyer. The dimensions of the handle were decided keeping in view the physiological dimensions of an average man and tree. On the top of the handle a ring made of mild steel rod having appropriate

Table 5. Design Details of Mango Harvesting Devices

Model	Weight of equipment (kg)	Length of equipment (m)	Blade	Ring	Collector	Cost of equipment (Rs.)
Impact type	2.296	3.0	One	Oval	Conveyer type	200.00
Shear type	2.426	3.0	Two	Oval	Conveyer type	240.00
Impact-cum-shear type	2.016	3.0	Three	Oval	Conveyer type	186.00
Local (Traditional)	1.700	3.0	Not used	Oval	Not used	100.00

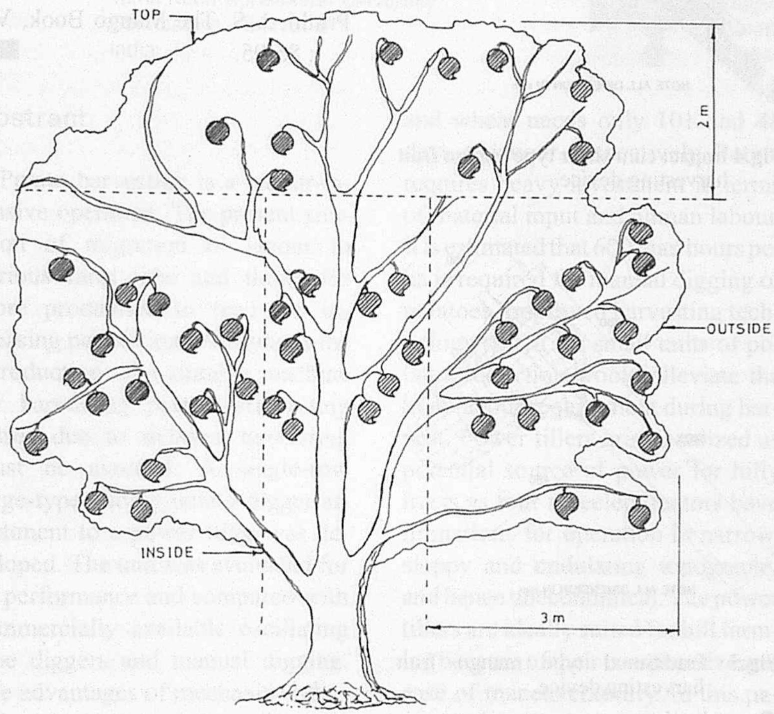

Fig.1 Mango fruits distribution within the tree.

size and shape was welded. A collector-cum-conveyer made of a nylon net was attached to the handle with the help of a number of hooks welded to the body of the handle. The upper end, larger in size, was attached to the ring to receive the harvested fruits and gradually reduced in diameter up to 15 cm.

The cutting mechanism which was one of the most important parts of the equipment was selected according to their working principle. In the impact type model, straight and plain blade of high carbon steel (40 × 25 mm) was used. It was welded to V-shape top on the divider as shown in **Fig. 2**. In the shear type model two straight and plain blades of high carbon steel were used. One of these blades was kept fixed and another could be operated with the help of a lever through a wire cable provided on the handle (**Fig. 3**).

For the impact-cum-shear type model, a circular serrated blade of 55 mm diameter made from high carbon steel (20 × 3.0 mm) was used. The circular blade was kept movable on the divider as shown in **Fig. 4**.

The different models of the mango harvesting device so developed were tested for their harvesting performance for the *Kesar* variety of mango at a farmer's orchard. The performance parameters were compared with that of the local device (**Fig. 5**). To harvest the fruit a well experienced operator was engaged. During testing, important observations such as number of fruits harvested per hour, stalk length, visible damage, shelf life of fruits, etc. were recorded. The cost of harvesting was also determined. The data collected are shown in **Table 6**.

Results and Discussion

The results recorded indicated that with the impact type of equipment, about 443 fruits could be harvested per hour (96 kg/hr). The average petiole length, visible damage percentage, shelf-life of fruits and cost of harvesting were calculated to be 1.5 cm, 6% and 23.41%, 15 days and Rs. 113/- per mt, respectively. The shearing type of equipment failed in the region because of the fibrous nature of the

Table 6. Performance Evaluation of the Mango Harvesting Devices

Model	Principle	Harvesting capacity: Number of fruits harvested / hour	Harvesting capacity: Weight of fruit (kg/hr)	Stalk length (cm)	Cost of harvesting (Rs./tonne)	Visible damage (%)	PLW (Avg.) (%)	Shelf life of fruit (days)
Impact type	Impact	443	96	1.5	114.00	6.0	23.41	15
Shear type	Shearing	-	-	-	-	-	-	-
Impact-cum-shear type	Impact-cum-shearing	438	92	1.2	118.00	4.0	23.64	12
Local	Impact	363	76	Non-uniform	182.00	12.0	24.52	10

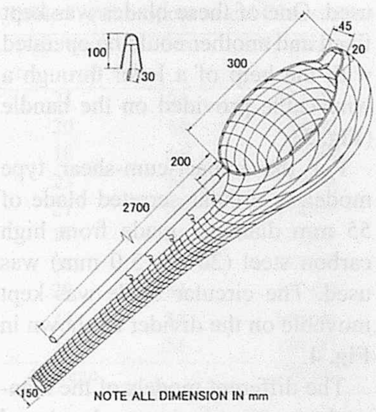

Fig.2 Impact type mango fruit harvesting device.

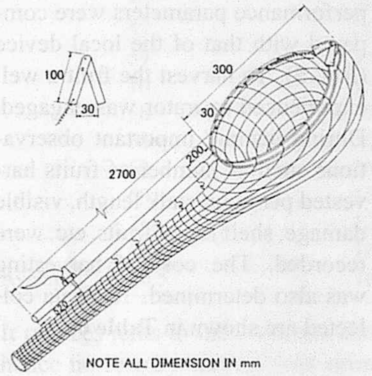

Fig.3 Shear type mango fruit harvesting device.

petiole of the *Kesar* variety of fruit. Hence, the model was discarded. With the third model, which works on the principle of impact and shearing forces, about 438 fruits could be harvested per hour (92 kg/ha). The visible damage, shelf-life of fruits and cost of harvesting were 1.2 cm, 4%, 23.46%, 12 days and Rs. 117 per mt, respectively.

The local traditional equipment could harvest only about 363 fruits per hour (76 /kg/hr). The petiole length of the fruits was not uniform. In fact, sometime fruits were harvested without petiole. Visible damage, plw, shelf-life of fruits and cost of harvesting were quite high at 12%, 24.52%, 10 days and Rs.182 per mt, respectively.

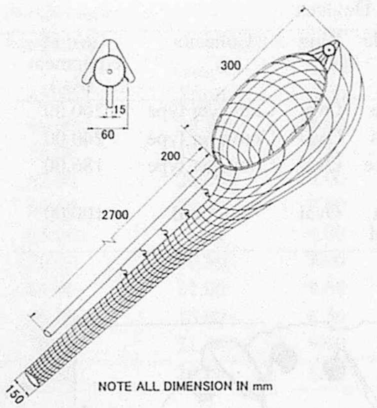

Fig.4 Impact cum shear type mango fruit harvesting device.

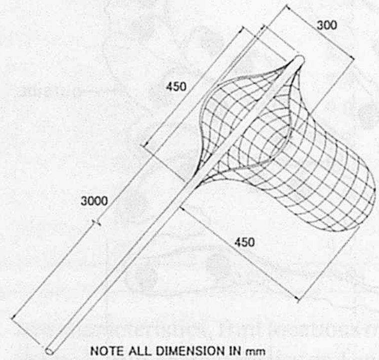

Fig.5 Traditional type mango fruit harvesting device.

Conclusions

From the results presented and discussion made, the following conclusions are drawn:

1. The harvesting capacity increased by 18% and visible damage to mango fruit decreased by 50% by using impact type model over the traditional harvesting device.
2. With the impact and impact-cum-shear type model, the petiole length of the fruit could be maintained 1 to 2 cm, which is highly desirable from quality point of view.
3. The shear type model was not found suitable for the harvesting of *Kesar* variety of mango due to fibrous nature of the petiole.

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A Power Tiller-based Potato Digger

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Abstract

Potato harvesting is a labour-intensive operation. The present situation of migration of labour to various farm jobs and thrust for more production to feed the increasing population necessitates the introduction of a suitable machine for harvesting potato. Harvesting losses due to delayed harvesting must be avoided. A single-row ridge-type sliding potato digger attachment to a power tiller was developed. The unit was evaluated for its performance and compared with commercially available oscillating type diggers and manual digging. The advantages of mechanized digging are highlighted.

Introduction

The contribution of potato to India's economy is manifold. Even though it is grown on just 0.6 percent of total cropped area, its value is estimated to be about 1.8 percent of the total output from agriculture during 1994-95. India occupies the fifth place in terms of area and production of potato. The national yield of 17 t/ha is higher than the world's average of 15 t/ha. Potato has excelled as the principal crop by registering higher growth rates during the last four decades. Potato, a horticulture crop, is widely adaptable and hence provides flexibility in production. While potato requires an input of 250 man days for cultivation in one ha, rice and wheat needs only 101 and 48 days of labour, respectively. Potato requires heavy investment in terms of material input and human labour. It is estimated that 600 man hours per ha is required for manual digging of potatoes. Improved harvesting technology suited for small units of potato production would alleviate the high labour requirement during harvest. Power tillers are visualized as potential source of power for hilly tracts as four wheeled tractors have limitations for operation in narrow, sloppy and undulating topography and hence uneconomical. The power tillers are ideally suited for hill farming because of their compact size and ease of maneuverability. In this paper the performance of two power tiller-based potato diggers was evaluated and compared with the conventional method.

Review of Literature

Dijkstra (1976) developed a potato digger which consisted of lifting, conveying and bagging sections. The lifting section included the digging share, depth control wheels, rod link elevator and haulm separator. Varma and Pathak (1977) developed a tractor mounted oscillatory potato digger. Chase *et al.* (1978) developed a self-propelled plot harvester equipped with a single blade. Misener and McMillam (1982) developed a single hill digger capable of digging hills of potatoes spaced at 450 mm apart and depositing them on the soil with the vines. Misener (1985) reported the development of a two-row tractor-mounted digger which is equipped with a hydraulic drive for flexibility and accommodating various harvest conditions. Sharma and Verma (1986) investigated the performance of a tractor drawn oscillatory potato digger and reported that reduction in weight of the blade reduced the vibration and improved the fatigue life in using the potato digger.

Methods and Materials

Various models of available tractor-mounted potato diggers are useful in areas where there is easy access and maneuverability for tractors. But in small and narrow bench terraces of hilly regions where potato is cultivated in large scale, power tiller-based digger is ideally suited for economic cultivation. A single-row potato digger as an attachment to power tiller was developed. The unit consists of a blade with a share point for digging potatoes. The blade in the shape of a ridger is attached at the bottom of the tool shank. The tool shank is provided with an off set beam and hitch point at the top portion. With this arrangement the tool shank with the blade can be off set to the right or left of the power tiller. At the top of the tool shank, a screw rod is also provided and the desired depth of penetration of the blade is

Table 1. Specification of the Potato Diggers

Particulars	Potato digger	
	VST Model	TNAU Model
Type	Mounted and oscillating	Mounted and sliding
Size of the blade, mm	500	385
Power requirement, hp	8 to 10 hp power tiller	
Over all dimensions (L × B × H), mm	1000 × 450 × 700	550 × 750 × 700
Weight, kg	42	26
Cost of the unit, Rs	6000.00	1500.00

Table 2. Performance Results of Potato Digging

Particulars	Potato diggers		Manual digging
	VST	TNAU	
Soil type	Lateritic loamy soil		
Topography of soil	Bench terrace of 4 to 7 m width		
Moisture content, percent	12 to 14		
Variety of potato harvested	KURFI JOTHI		
Crop spacing, mm	Row to row 450 and plant to plant 200		
Seed rate/ha	40 gram seeds; 3000 Nos.		
Speed of operation, kmph	1.44	1.40	-
Depth of operation, mm	200	210	-
Width of operation, mm	510	390	-
Area covered, m^2/hr	496	463	148
Weight of potato collected, kg/hr	704	657	210
Time required to dig one ha, hrs	20.2	21.6	67.6
Damaged potato, percent	5.2	1.4	1.1
Undug potato, percent	8.18	5.3	2.1
Cost of operation, Rs/ha	3243.75	3303.75	5869.75
Savings in cost, percent	44.7	43.7	-
Savings in time, percent	70.1	68.0	-

Fig.1 Potato digger (TNAU model).

Fig.2 Potato digger (VST model).

adjusted by rotating the screw rod (**Fig 1**). Slats are fixed at the rear portion of the ridger blade on both sides. For digging the potatoes planted in ridges, the blade with the share point penetrates into the soil, digs out the potatoes along with the soil and conveys it to the slats. The soil slips back to the ground through the slats and the dug potatoes are deposited on the soil. The power tiller-drawn mould board plough can be easily converted as potato digger by replacing the mould board and share with digger bottom.

The commercially available power tiller-operated potato digger (VST model) was also used for digging potatoes. The unit consists of two blades with slats hinged at one end.The oscillating motion is obtained through eccentric provided on either side of the unit and connected to a shaft (**Fig. 2**). The power is transmitted from the power take off (PTO) pulley of the power tiller through a V belt transmission. For digging, the two blades dig into the soil and lift the potatoes along with the soil. When the dug potatoes with soil travel along the slats, the oscillating motion separates the potatoes from the soil. The potato slips back to the ground and the dug potatoes gets deposited on the soil. The specification of the potato diggers are shown in **Table 1**.

The two models of the potato digger are evaluated for digging potatoes planted in ridges and furrows in a private farm, namely; Arundale Farms, Ooty. The performance was compared with the conventional method of manual digging. The observations on coverage, quantity of potatoes dug and damage sustained were recorded. The related data in the conventional system followed, i.e., manual digging with Guddali were also recorded.

Results And Discussion

The performance results of the two potato diggers and the manual digging of potatoes is shown in **Table 2**.

The time required to dig one ha of land was very much less in the case of power tiller based diggers when compared to manual digging. As a result of which the weight of potatoes dug and collected per unit time was also great. In the case of the VST digger, the damage sustained by the potatoes was almost five times that of manual digging as the two dividers on either side of the unit extend up to 750 mm and damaged the potatoes in the adjacent rows. The damage sustained by the potatoes the TNAU digger is insignificant compared to the VST digger and it is almost comparable with the damage caused by manual digging. The percentage of potatoes left covered by the soil and undug was maximum (8.18 percent) in the case of the VST digger followed by the TNAU digger (5.3 percent). This is due to the fact that the power tiller could not reach the extreme ridge on both sides of the bench terrace. The reason for the minimum percent of potatoes left out in the case of manual digging was the harvesters were well-trained. Moreover it was the traditional practice followed for several years now. It is observed that the digging potatoes using the VST model and TNAU model potato diggers resulted in 44.7 and 43.7 percent saving in cost and 70.1 and 68.0 percent savings in time, respectively, when compared to manual digging.

Conclusions

Based on the analysis of the results, the following conclusions are drawn:

1) Digging potatoes with power tiller based-diggers resulted is highly economical as about 44 percent savings in cost is achieved when compared to the manual digging. This will alleviate the high labour requirement during the peak harvest season.
2) The power tiller-operated diggers ensure timeliness of harvesting since 68 to 70 percent of savings in time is obtained. Field losses due to delayed harvesting could be minimized.
3) The damage sustained by the potatoes using the TNAU digger is almost the same as that of the manual digging and the higher percentage of damage sustained by the potatoes in the case of the VST digger can be minimized by incorporating suitable modifications.
4) Since the digger blade bottom alone is necessary for converting the mould board plough into potato digger in TNAU model, the over all initial investment is reduced.

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Fabrication and Performance Evaluation of a Brinjal Seed Extractor

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Abstract

A brinjal seed extraction unit with 120 kg/h capacity consisting of crushing chamber and seed separation unit was developed and evaluated for its performance. The unit was optimized by varying the operating parameters viz., rotor shaft speed, water for fruit crushing, number of rods in crushing rotor and crushing rod spacing. The extraction efficiency of the unit was 96.51 percent with 91.68 percent germination. The saving in time and cost were 97.5 and 88.9 percent, respectively.

Introduction

Vegetables play an important role in human nutrition. Vegetables are rich in minerals, proteins, vitamins, carbohydrates and roughages which are highly essential and vital for human health. The area planted to vegetable crops in India is around 4.5 million ha. India is the second largest producer of vegetables next to China with an estimated production of 70 million tonnes. However, the daily per capita consumption of vegetables in India is only 135 g which is far lower than the daily requirement of 400 g for a balanced diet. Non-availability of good quality seeds, is one of the important factors for low vegetable production.

Brinjal (*Solanum melongena*) otherwise called eggplant, belongs to the solanaceae family, a non-seasonal crop and largely grown throughout India. The area planted to brinjal cultivation in India is 0.45 m.ha, with a production of about 5.8 million tonnes. The extraction of seeds from the brinjal fruits is presently carried out manually. Manual extraction techniques include beating the fruits with mallet, trampling under feet, squeezing with hands and splitting with hand tools followed by scooping the seed with hand (Verma *et al.*, 1992). Manual extraction also includes cutting the fruits into pieces and soaking them in water for 24 to 48hr followed by squeezing. Manual seed extraction is unhygienic, tedious and a highly time and labour consuming process. In addition, dependence on human labour for seed extraction process leads to delay which results in seed loss and exposure of seeds to adverse weather conditions causing deterioration of seed quality and increased cost of seed extraction. Mechanical seed extraction process reduces the time and cost of seed production and helps in the production of quality seeds. Hence, a brinjal seed extractor was developed for wet seed extraction from fresh fruits.

Review of Literature

Nicholas (1971) developed a vegetable-seed extracting machine consisting of a shaft with beaters rotating inside a horizontal drum. Two outlets were provided to collect the extracted screened out seeds and juice. Dry feeding of brinjal resulted in 75 percent of seed extraction and the capacity was 10 kg/h.

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Kachru *et al*. (1986) reported about a manually-operated tomato seed extractor. The machine has a rotary cylinder with corrugations on the surface which was rotated inside a metal concave. The cylinder was rotated at 40-50 rpm by a handle mounted on the drum shaft. An auger mounted on the cylinder carried the pulp and skin forward while the juice and seeds were collected below the cylinder. The juice and seeds were kept for fermentation for 24 hours to remove gelatin coat after which the seeds were separated through screening and then washed, cleaned and dried.

Devadas *et al*. (1993) fabricated a horizontal type tomato seed extractor. The operation was done in batches by a 1.5 hp, 1440 rpm motor. Seed extraction was 85 percent and the capacity of the machine was 60 kg/h.

Gabani and Siripurapu (1993) developed a chilly seed extractor operated by a 1440 rpm electric motor.

Mohanty *et al*. (1997) developed a low-cost vegetable seed extracting machine operated by 0.5 hp motor. Water was sprinkled during seed extraction. The capacity of the extractor was 210.96 kg/h for tomato at 370 rpm with an average seed extraction efficiency of 84.7 percent.

Features of the Machine

The two main components of the newly developed brinjal seed extractor were the fruit crushing chamber and the seed separation unit.

The Fruit Crushing Chamber

Frame

The frame was made of mild steel angle iron section of 50 mm x 60 mm size. It has a trapezoidal shape. The height of the frame was 0.91 m. The frame was well braced to provide rigidity to mount and support other parts of the machine and to withstand vibrations due to high speed of the rotor.

Feed hopper

A feed hopper of trapezoidal shape was fabricated in a 3 mm thick mild steel sheet to induct brinjal fruits into the crushing chamber. The length of the feed hopper was 0.455 m. The width at the front was 0.29 m and 0.14 m at the rear side. The hopper was placed at an inclination of 34° to the horizontal.

Rotor shaft

The rotor shaft of 32.5 mm diameter and 0.88 m length was mounted on two ball bearings and allowed to rotate freely in the crushing chamber. Mild steel rods 10 mm diameter and 75 mm were bolted in the shaft in a helical path so as to perform dual action, i.e., cutting of fruits and conveying of the pulp simultaneously in the crushing chamber.

Pulp outlet chute

One pulp outlet chute was provided at the extreme end of the crushing chamber casing to convey the pulp and seed mixture to the separation unit. The chute was made of 3 mm thick mild steel plate and attached to the bottom of the separation unit. Although both ends of the pulp outlet chute were welded to the separation unit and casing of crushing chamber, a flange arrangement provided in the middle helps easy separation of the crushing chamber from the seed separation unit.

Cover

A cylindrical cover made of 3 mm thick mild steel sheet was provided over the entire length of the rotor shaft to form a crushing chamber. The radius of the cylindrical cover was 200 mm. The length of the cover was 0.60 m. The cover was made into two equal halves and hinged on one side and bolted on the other side for easy opening and cleaning of crushing chamber. An inclined tray type feed hopper was welded on the top half of the cover at the feeding end. As the size of the brinjal seeds is only 3 mm, a clearance of 4 mm was provided between the cover and the tip of the rods for crushing the brinjal fruit into pulp without causing damage to the seeds.

An electric motor of 3 hp was selected to drive the rotor shaft. Power was transmitted from the motor to the rotor shaft by means of V-belts and pulleys.

The Separation Unit

The separation unit has a large cylindrical drum in which water was filled up to the pulp outlet level prior to starting of seed extraction. Since the specific weight of brinjal pulp (0.875) was less than the specific gravity of water, the pulp floats on water. The pulp that floats is separated at the top of the separation chamber through the pulp outlet. The specific weight of seeds (1.23) is heavier than water and settle at the bottom.

The cylindrical drum was 400 mm in diameter and 520 mm in height and made out of 1 mm thick mild steel sheet.

Agitator shaft

The agitator shaft houses the radial arms and brush arrangement. The diameter of the agitator shaft was 30 mm and was made of mild steel rod.

Radial arms

The arms were fixed helically such that on rotation, they not only disperse the pulp and seeds in the water but also conveys the pulp material towards the top of the drum. In total, six radial arms were provided. The length of each radial arm was 170 mm. The arms were made out of 12 mm mild steel square rod.

Brush

A nylon brush was attached to the agitator shaft such that it moved over the sieve arrangement continuously and prevents clogging of the sieve. The length of the brush was 170 mm. It was fixed to the agitator shaft through a bush with the help of bolts and nuts.

Sieve

The sieve is an essential part of the seed separation unit which allows the seeds to pass through it and prevents entry of pulp. As the normal size of brinjal seeds is 3 mm, a wire mesh with hole size of about 4 mm (BSS 7 size) was selected. It was riveted on a mild steel flat of 4 mm thick and positioned at a height of 85 mm from the bottom of the cylindrical drum.

Pulp outlet

The pulp outlet was provided at the top of the drum. Since the specific weight of pulp was lower than water, it floats and due to agitation the pulp gets separated from the seed and moved towards the top. The pulp outlet was made of 1 mm thick mild steel sheet in a rectangular shape.

Seed outlet

The seed outlet was provided at the bottom of the separation unit. The seed outlet was a pipe of 38 mm inner diameter. To this pipe, a gate valve of 38 mm inner diameter was fixed. The seeds were collected through the gate valve along with water which flow is regulated.

Drain cock

A 38-mm inner diameter pipe coupling was welded to the drum at a height of 80 mm from the bottom of the drum and fitted with a suitable end plug. The drain cock is to drain the pulp and water mixture above the sieve at the end of seed extraction process. This is provided for easy cleaning of the separation unit.

Power transmission system

For the efficient separation of seeds from the pulp, the seeds and pulp mixture required slow agitation in the standing water column in the separation unit. Using a two-stage speed reduction system, the agitator shaft is made to rotate at a slow speed of 35 rpm to get the proper dispersion of seeds and pulp.

A rectangular frame was made of mild steel angle iron section of 25 × 25 × 4 mm. The length of the frame was 0.92 m, width 0.45 and height 0.90 m. All other components of separation unit were attached to it.

Materials and Methods

After fabrication of the machine, it was tested and its performance was evaluated. The performance of the machine was compared with the existing method of manual extraction of brinjal seeds.

The mechanical extraction of brinjal seeds involves feeding, crushing, pulping and collection of seeds and pulp through separate outlets. The brinjal fruits are crushed and the pulp and seeds are separated. The seeds collected were then dried in the shade. During feeding, water was added along with the brinjal fruits. In the manual method of seed extraction, 5 litres of water was used per kg of brinjal fruits. Hence, in the mechanical extraction process, two water flow rates namely 3 l/min and 5 l/min per kg of brinjal fruits were selected. The experiments were conducted for single and double crushing rods with different water flow rates (3 and 5 l/min) for three levels of speed of the rotor (1700, 2200 and 2800 rpm) at three crushing rod spacing (20, 40 and 60 mm). The feed rate was kept constant at 120 kg of fruits per hour in all tests.

Seed loss was determined from the seeds recovered from the pulp outlet and from the drained water. The entire pulp and other waste materials collected from the pulp and drain outlet during each test were put in water separately and the seeds, if any, were separated by washing. Later, the seeds were dried in the shade. The percent seed loss was determined on the basis of total seeds recovered from both pulp and seed outlets as follows:

$$\text{Percent seed loss} = \frac{S_2}{S_1 + S_2} \times 100$$

Where,

S_1= weight of seed collected from seed outlet, g

S_2= weight of seed passed through pulp outlet and drain water, g

The procedure for determination of seed extracting efficiency (percent) of the newly developed machine was the same as that of finding the percent seed loss:

Seed extracting efficiency,

$$\text{Percent} = \frac{S_2}{S_1 + S_2} \times 100$$

Seed germination

According to the International Standards for seed testing, the top of paper method of germination was adapted for the brinjal seeds. Representative samples in triplicate from each of the seed lots which were extracted during different test conditions of the machine were taken for the germination studies.

Results and Discussion

The results obtained using single crushing rod, mounted on the rotor shaft at 20, 40 and 60 mm spacing and arranged in a helical path and operated with 3 and 5 litre per minute fruit crushing feed water flow rates are illustrated in **Fig.1**.

From the figure, it is seen that the seed extraction efficiency at 3 litres of water increased until the spacing of crushing rod was 40 mm and then showed a decreasing trend. Similarly, among the three rotor shaft speeds studied, the seed ex-

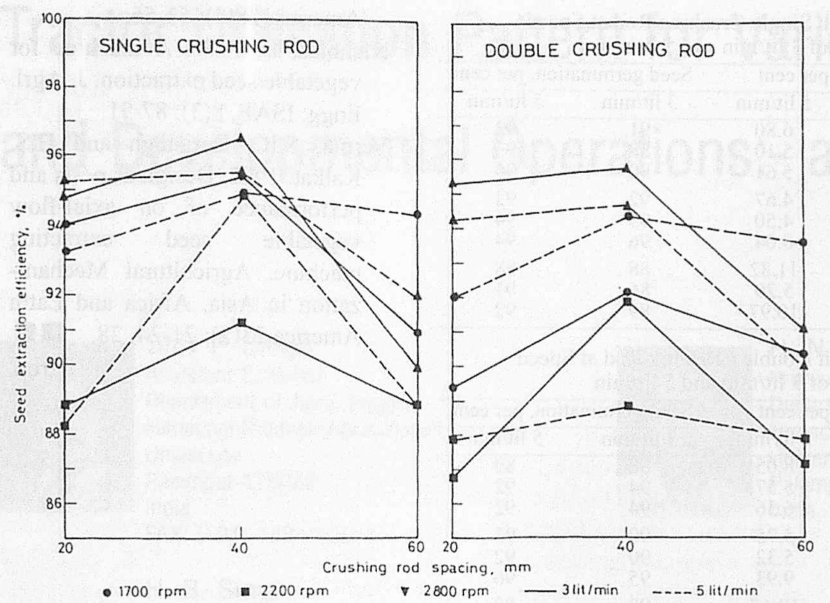
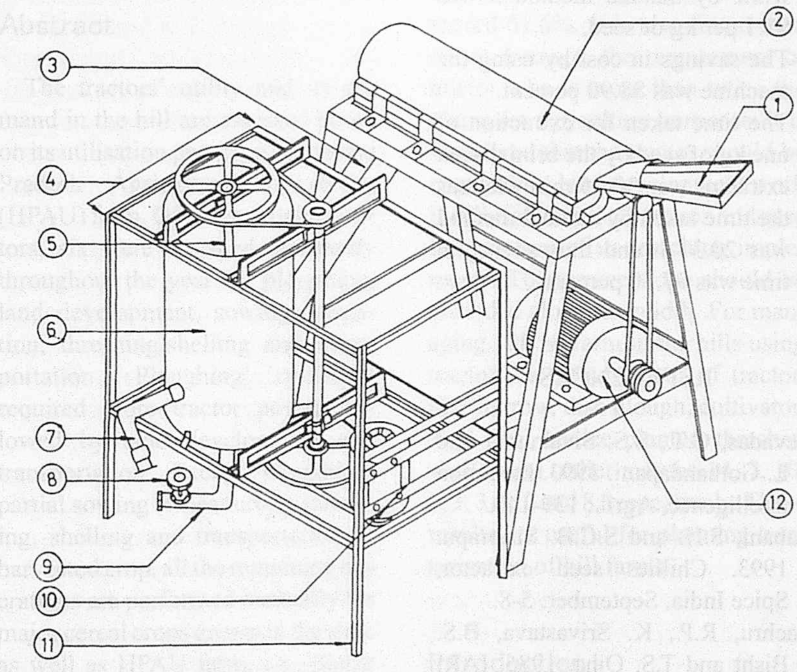


Fig.1 Seed extraction efficiency with single and double crushing rods at 3 and 5 liter/ minute fruit crushing feed flow rates.



1. FEED HOPPER	7. DRAIN COCK
2. FRUIT CRUSHING CHAMBER	8. GATE VALVE
3. PULP OUTLET	9. SEED OUTLET
4. SEED SEPARATION UNIT	10. ELECTRIC MOTOR, 0.5 hp
5. AGITATOR SHAFT	11. FRAME
6. CYLINDERICAL DRUM	12 ELECTRIC MOTOR, 3 hp

Fig.2 Isometric view of the brinjal seed extractor.

traction efficiency increased up to 2200 rpm and then started decreasing, i.e., at less rod spacing (20mm), the higher number of crushing rods helped to convey the fruits rather than crushing the same into pulp whereas more rod spacing (60 mm) cut the fruits into larger pieces instead of pulping. Hence, seed loss was greater both at 20 and 60 mm spacing. At 40 mm spacing the fruits were pulped properly and hence the seed extraction efficiency was high. Similarly, at low speed (1700 rpm), of rotor the fruits were not crushed into required size and discharged as small lumps whereas at higher speed, the fruits got conveyed quickly in the crushing chamber and did not pulp well. At medium speed (2000 rpm) the fruits were crushed into required size in the crushing chamber and thus higher seed extraction efficiency was recorded.

Although a similar trend was observed with 5-litre water/minute, the seed extraction efficiency was low in all cases which may be due to high buoyancy effect of water rather than the pulping action.

Fig. 2 represents the test results of double crushing rods operated at 1700, 2200 and 2800 rpm with 3 and 5 litre of water /minute. The 40 mm rod spacing with 2200 rpm speed recorded higher seed extraction efficiency of 96.51 percent. However, due to double crushing rod, damage due to impact caused to the seed was greater and hence recorded lower seed germination which lowered the overall effect of seed extraction and seed germination when compared to the single crushing rod.

The seed loss and seed germination with respect to different operating conditions are given in **Tables 1** and **2** with the single crushing rod, the seed germination increased due to the fact that at lesser spacing, greater number of crushing rods cause damage to seeds due to impact force. In double crushing

Table 1. Performance of Seed Extractor with Single Crushing Rod at Speed Extraction Feed Water Flow Rates of 3 lit/min and 5 lit/min

Rotor shaft speed, rpm	Crushing rod spacing, mm	Seed loss, per cent		Seed germination, per cent	
		3 lit/min	5 lit/min	3 lit/min	5 lit/min
1700	20	6.06	6.80	91	92
	40	4.60	5.10	88	93
	60	8.96	5.61	90	96
2200	20	5.20	4.67	92	92
	40	3.49	4.50	95	94
	60	9.99	8.04	96	94
2800	20	11.13	11.82	88	88
	40	8.80	5.20	86	91
	60	11.16	10.97	89	92

Table 2. Performance of Seed Extractor with Double Crushing Rod at Speed Extraction Feed Water Flow Rates of 3 lit/min and 5 lit/min

Rotor shaft speed, rpm	Crushing rod spacing, mm	Seed loss, per cent		Seed germination, per cent	
		3 lit/min	5 lit/min	3 lit/min	5 lit/min
1700	20	10.58	8.05	88	89
	40	7.77	5.57	94	92
	60	9.56	6.36	94	92
2200	20	4.11	5.75	90	93
	40	3.17	5.32	90	92
	60	4.32	9.93	95	96
2800	20	13.30	12.17	88	88
	40	8.07	11.18	90	90
	60	12.88	12.28	92	94

rod with more spacing increased the seed germination.

Considering the overall effect of seed extraction efficiency and seed germination simultaneously, the brinjal seed extraction unit with single crushing rod placed at 40 mm spacing operated at 2200 rpm rotor speed with 3 litre/min of water gave the maximum of 91.68 percent seed germination for the seeds present in the fruit and hence adjudged as the best operating condition.

The cost of operation of the prototype was compared to that of manual method of seed extraction. The cost of the unit was $345.00 and the cost of operation was estimated at $0.25 per kg of seeds.

Conclusions

1. The best operating condition was obtained at a rotor speed of 2000 rpm with 40 mm single crushing rod spacing and 3 litre/min of water seed germination was recorded at 91.68 percent of total seeds present in the brinjal fruit.
2. The cost of the brinjal seed extractor was $345.00.
3. The cost of seed extraction per kg of seed, by mechanical seed extraction method was $0.25 while by manual method it was $2.1 per kg of seed.
4. The savings in cost by using the machine was 88.90 percent.
5. The time taken for extraction of one kg of seed by the brinjal seed extractor was 30.45 min whereas the time taken by manual method was 20.37 h and thus saving in time was 97.50 percent.

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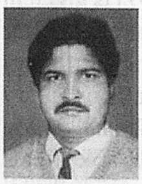
Tractor Utilisation Pattern for Various Agricultural and Developmental Operations:- a Case Study

by



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Abstract

The tractors' utility and its demand in the hill are assessed based on its utilisation pattern at Himachal Pradesh Agricultural University (HPAU) farm. Of seven regular tractors, six were engaged constantly throughout the year for ploughing, land development, sowing, irrigation, threshing/shelling and transportation. Ploughing operation required more tractor power followed by land development and transportation. Except ploughing, partial sowing (wheat crop), threshing, shelling and transportation of harvested crop, all the remaining operations are performed manually for major cereal crops grown in the state as well as HPAU farm, i.e., maize and wheat crops. It is found that tractors helped in enhancing 26.96% more area for agricultural purpose at the farm. It is observed that less sowing time was available for maize as compared to wheat crop. It is estimated that for maize and wheat cultivation, 61.98 tractor-h/ha is required of which wheat cultivation shared 61.6%. It is also found that, on an average, the requirement of tractor h/ha is more than twice the plains for agriculture purposes. It is visualized that the tractor should be engaged for land development work in hills for its full utilization and ease in operation of its matching implements. The terrace slope should be provided along the width. For managing 100 ha farm in the hills using tractor, the requirement of tractor, disc harrow, disc plough, cultivator, seed drill, maize planter, thresher, sheller and trailer may be 14, 7, 10, 9, 3, 3, 3, 2 and 8, respectively. These results are useful for planning tractorisation of hill farms.

Introduction

Tractors play a vital role for mechanising agriculture in plains resulting in the introduction of multiple cropping. It also help in enhancing the total cropped area by developing non-agricultural land into cultivated land (Pannu et.al. 1992). The National Commission on Agriculture has indicated that energy input to agriculture will have to be raised from 0.39 to 0.89 hp/ha by the year 2000 AD in order to double the food grain production (Sandge, 1986). Singh and Tandon (1987) reported that the state of Punjab, Haryana and Uttar Pradesh together accounted for about 67% of the total number of tractors in India. Verma et.al. (1987) reported that Punjab alone accounts for about 25% of tractors available in the country. In spite of these developments, the utilization of tractors in hilly areas is low due to its restricted use in the present form of small terraced land with high vertical intervals. The average land holding in Himachal Pradesh is 1.21 ha of which 43.17% of total cultivable land is held by marginal and small farmers with an average land holding size of 0.64 ha (Anon., 1990). Singh and Verma (1998) reported that there is a need to increase at least 5% more area under crop cultivation in Himachal Pradesh which is possible only through tractorisation. Recently, tractors have attracted big farmers and government organiza-

Table 1. Area Distribution of the Himachal Pradesh Agricultural University

Classification	Area (ha)
Total area	416.48
Building area	68.0
Horticulture and tea	46.0
Area left for agriculture, grass land, animal husbandry and forestry	302.43
Developed area for agriculture and animal breeding	158.7
a) type - Bench way terraces = 104.7 ha	
- Broad based terraces = 54.0 ha	
b) Use	
i) Seed farm and Use by the departments = 73.7 h	
ii) Animal Breeding = 85.0 h	
Can be developed into fields	5.50
Cannot be developed into fields	138.2

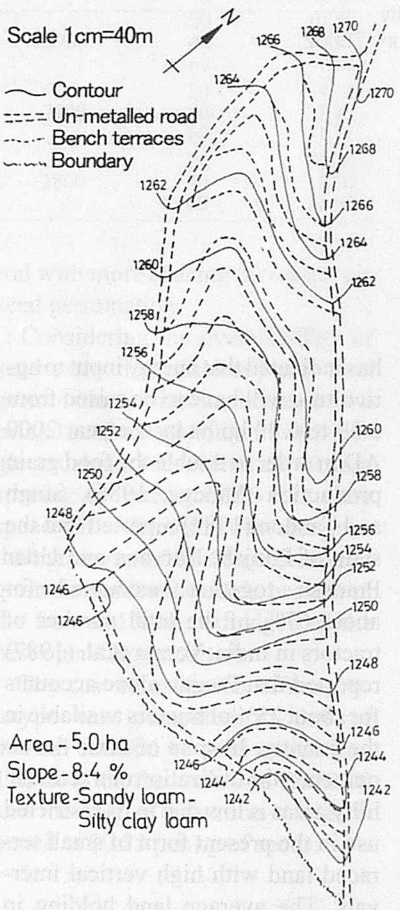

Fig.1 Topography of representative cropped sub-watershed at HPAU farm.

tions of the hilly states for their utilization to enhance agricultural production and social living due to its versatility. However, some medium-sized farmers have also procured tractors in the state for transportation and seasonal ploughing and threshing. No systematic work has been carried out to find tractor utilisation in hills and its impact on land development and agriculture. This paper presents the actual use of tractors and machines at HPAU farm as a case study which can be used for mechanisation of the hill agriculture.

Material and Methods

The Himachal Pradesh Agricultural University (HPAU), Palampur is situated at an altitude of 1280 m above mean sea level beneath Dhauladhar range of Himalaya. The information regarding area, farm machines, farm power and crops grown is collected from the University farm, i.e., Seed Production Unit. The working hours of tractors and their engagement in various operations during the last five years were recorded from the log book kept at the farm. The desired hours of use of different implements and tractors for a particular crop was calculated on the basis of agricultural practices recommended by the HPAU, and using field capacity of different tractor-drawn implements. The field capacity of implements depended on their size. The field capacity of implements were recorded and used in the calculations. The field capacity of 1.9 m disc harrow, 9 tines cultivator, 3 discs plough, 9 tines maize planter and seed drill were 2.2, 2.2, 1.4, 3 and 2.8 ha/day, respectively, where a day was taken as 8 working hours. For obtaining the field capacity of sheller and thresher, the average grain yield and output of sheller/thresher were taken into account, i.e., 25 and 40 q/ha and 5.56 and 7.5 q/h, respectively. Thus, the capacities of sheller and thresher were 1.78 ha/day and 1.5 ha/day, respectively.

Results and Discussion

The area distribution of HPAU at main campus (Anon., 97) is given in **Table 1**. From the table it is clear that 72.6% of the area is left for agriculture, grass, animal husbandry and forestry. Of the 302.4 ha, 52.5% is developed into cultivable fields and only 1.82% more area can be developed. The rest, 45.7%, cannot be developed because of stony strata and shallow top soil. Of the developed area, 46.4% area is under agricultural crops by the Seed Production Unit and various departments, excluding animal breeding which maintains 85 ha separate land for raising fodder for cattle. These areas were developed into bench way and broad based terraces. A topographical map of a representative sub-watershed of the HPAU farm is shown in **Fig. 1** which reflects the terrace size, vertical intervals and slopes. Maize and wheat are the major crops grown at the farm. However, soybean, paddy, bhindi, mash, kulthi, til, and beans were also grown in Kharif season. Barley, oats, gobhi sarson, raya, brown sarson, toria, peas, radish, turnip, broccoli, methi, onion, garlic etc. are grown in Rabi season. The whole area is rainfed except patches of vegetables and some other crops with limited irrigation. Major land development in the form of terraces was done in 1980-83. After 1983-84 refinement/redevelopment of terraces were taken up regularly (**Fig. 2**). It is observed that up to 1980, the net area available for agriculture purpose was 125 ha (Anon., 1994) which has been increased by 26.96% due to the introduction of tractors at the farm.

Table 2. Farm Machinery Availability at the HPAU Farm*

Implements	Number
Hand Tools	
- Spade	25
- Khunti	25
- Hand plough	15
- Sickle	30
- Sprayer	1
Tractor Drawn	
- Cultivator	3
- Disc plough	3
- Disc harrow	2
- Seed drill	1
- Leveller	2
- Thresher	2
- Sheller	2
- Power sprayer	1
Prime Mover	
- Tractor	7
Miscellaneous	
- Trailer	4

* In addition to this each department has its own set of hand tools and equipment.

Availability of Farm Machinery and Power

Table 2 shows the available farm machineries and power at the University farm. The farm has sufficient number of tools/implements for seedbed preparation, manual weeding, sowing and harvesting, and transportation. It has sufficient number of tractors but inadequate number of seed drills, maize planters, weeders and hoes. Most of the sowing, weeding, earthing and harvesting operations are carried out by farm workers. There is, thus, scope to increase the use of existing tractors by using matching implements for maize sowing, weeding, earthing and harvesting.

Engagement of Tractors

The engagement of tractors at the farm is given in **Table 3**. Of the 4386 hours of tractor utilization, 45.32% hours were used in ploughing, 26.17% in developmental work, 24.17% in transportation, 3.48% in threshing and shelling, 0.74% in sowing and 0.27% in irrigation works. The peak demand for tractor is for ploughing, i.e., May-June during Kharif season and September-December during Rabi season. The lean period (December-April) is utilized by engaging tractors in developmental work like land grading, pond making, construction of farm road, etc. The demand for tractors in transportation work is almost constant throughout the year. The table also suggests that six tractors were constantly engaged throughout the year except in the month of July and August. Low use of tractors in July and August may be due to continuous wet days and high rainfall (Verma et.al., 1994). It is also observed from the table that these tractors were engaged mainly for ploughing, developmental and transportation works. The field capacity of disc plough, disc harrow and cultivator was found nearly 2.5 times less and for seed drill, it was 1.61 times less than that of plain areas (Pannu, et. al., 1987) suggesting that the power requirement per unit area for agricultural work is greater in the hills than the work in the plains.

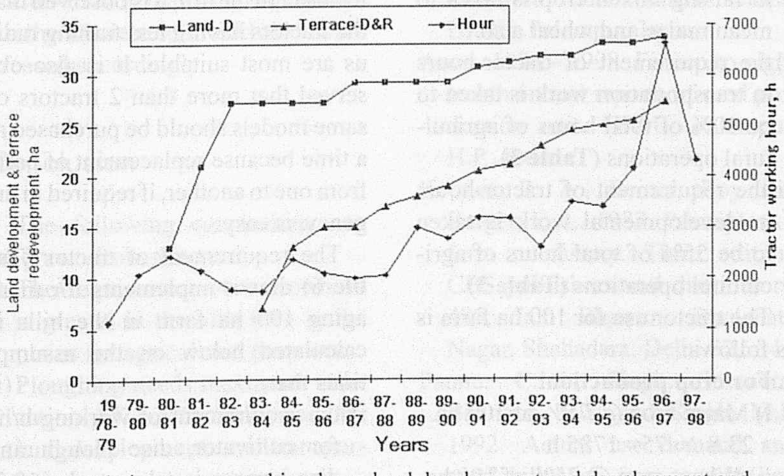

Fig.2 Cumulative tractor working-hour, land development and development and refinement of tractor pattern at HPAU farm.

Cultivation Practices

In Kharif season, for maize cultivation, the first ploughing is done using disc plough just to open the land and after this, ploughing operation is performed with disc harrow (once) and cultivator (twice) followed by planking to conserve moisture. Sowing is done normally through hand plough (manual) by engaging farm workers. Kharif sowing is done normally in line across the terrace length (along width) which restricts the use of the maize planter. Maize crop needs earthing after one month which is also done manually. To use the maize planter and earthing equipment, it is necessary to provide terrace slope towards the direction of smaller dimension, i.e., width for ease of their operation through tractor along the length and this will also not hamper the drainage of rain water and conserve soil and water. Except for ploughing, threshing and transportation of harvested crop, all the remaining operations are performed manually.

In rabi season, after maize crop, wheat requires 1-2 more tillage operations than maize crop because of erasing of bunds, mixing of FYM and better tilth required for wheat. Wheat sowing is done manually through hand plough and also partially through seed drill. It is also observed during sowing with seed drill that the tines of the machine get damaged frequently due to presence of stone boulders which suggests that the quality of material of machine should be quite satisfactory. The remaining operations are performed manually.

Demand and Utilization of Farm Tractor and Implements

Maize and wheat are the major crop rotations in the state (Singh,

Table 3. Average Monthly Use of Tractors at HPAU Farm for Different Operations (Unit: Hours)

Month	Average Working Hours	Various Operations							Av. Tractor Engagement
		Ploughing	Levelling/Land Development	Sowing	Irrigation	Threshing	Shelling	Transportation	
June	476.6	311.2	5.0	-	-	47.6	-	113.0	6.0
July	149.2	76.2	9.2	-	0.40	0.6	-	62.8	5.4
August	151.8	76.6	8.4	-		-	-	66.8	4.0
September	358.4	256.0	10.6	-			-	91.8	6.6
October	528.4	414.6	22.6	-	-	0.6	-	90.8	6.4
November	530.2	371.4	22.2	12.8	-	21.2	8.2	94.4	6.0
December	448.6	232.4	91.8	19.6	-	3.8	3.8	97.2	5.8
January	340.6	39.2	211.2	-	0.8	1.0	-	88.4	5.0
February	281.6	11.0	192.6	-	0.2	1.2	-	76.6	6.6
March	396.0	23.4	281.4	-	3.4	-	-	87.8	6.2
April	284.6	35.2	184.4	-		-	-	64.6	5.6
May	440.2	141.2	108.4	-	-	64.8	-	126.2	6.2
Total	4386.4	1988.0	1147.8	32.6	4.8	140.8	12.0	1060.4	69.8
Average working hour/ month	365.56	165.67	95.65	-	0.4	11.73	1.0	88.37	5.82

Table 4. Operational Days Available for Sowing of Major Crops

Crops	Sowing Time	Harvesting Time	Period Available for Sowing, days
Maize	Last week of May to 2nd week of June	Last week of Sept. to 1st week of October	15
Wheat	1st to Last week of Nov.	2nd to 3rd week of May	21

1998) as well as of the University farm. **Table 4** shows the time available for sowing and harvesting of the main crops. Less time is available for maize as compared to wheat. Based on the package of practices, the expected use of hours/ha for various implements and prime mover is given in **Table 5** clearly indicating that the prime mover (tractor) is required for 23.8 h/ha in maize crop cultivation for disc ploughing, harrowing, cultivator, sowing and shelling, whereas in wheat crop cultivation, tractor is required for 38.18 h/ha for harrowing, disc ploughing, cultivator, sowing and threshing. The cultivator needed greater tractor -h/ha in both crops. The tractor utilisation pattern at HPAU farm w.e.f. July, 1978 to June, 1998 is given in **Figure 2**. From the figure it is clear that the utilization of tractor hours have increased from 1130 to 6616. The figure also suggests that the average use of tractor at the farm is more than 4000 h a year. The first tractor was purchased in July, 1978, 2nd in April, 1979, 3rd in February, 1984, 4-6th in August, 1988 and 7th in February, 1993.

Requirement of Tractor and Implements

For managing 100 ha farm in the hills, the requirement of a tractor is calculated with the assumptions that:

i) 75% of the area is under maize and wheat cultivation;

ii) the rest of the area is under mixed crop cultivation; and

iii) the requirement of tractor h/ha, in raising maize and wheat crop is taken at 23.8 and 38.18, respectively.

iv) the requirement of tractor h/ha, in raising mixed crop is taken to mean maize and wheat also.

v) the requirement of tractor-hours in transportation work is taken to be 50% of total hours of agricultural operations (**Table 3**).

vi) the requirement of tractor-hours in developmental work is taken to be 55% of total hours of agricultural operations (**Table 3**).

The tractor use for 100 ha farm is as follows:

1. For crop production:

i) Maize crop @ 75% of 100 ha.
$23.8 \times 75 = 1785$ h

ii) Wheat crop @ 75% of 100 ha
$38.18 \times 75 = 2863.5$ h

iii) Other crops in the rest of 25% area, @ 30 h/ha
$30 \times 25 = 750$ h

Total = 5398.5 h

2. For transportation purpose
@ 50% of 5398 h
= 2699 h

3. For land development purpose
@ 55% of 5398 h
= 2968.9 h

Total tractor use
= 11066.4 h

Prime mover (tractor) required @ 1000 h/tractor/year (Kepner et. al., 1987) is thus
= 11.07 = 11

The net requirement of tractor for managing 100 ha farm in the hills is 11 but the actual need for tractor should be at least 25% more (14 tractors) to take care of repair and maintenance. In the hill, it is observed that the tractors having less turning radius are most suitable. It is also observed that more than 2 tractors of same models should be purchased at a time because replacement of parts from one to another, if required in urgency, is easy.

The requirement of tractor (**Table 6**) drawn implements for managing 100 ha farm in the hills is calculated below on the assumptions that;

i) the requirement of working-h/ha for cultivator, disc plough and disc harrow is taken to be 18.2, 17.13 and 10.92, respectively.

Table 5. Demand and Utilisation of Various Implements for Major Crops

Crop	Disc Plough			Disc Harrow			Cultivator			Maize Planter*	Seed drill	Thresher	Sheller	Prime Mover
	Expected use of working hour/ha													
	1	2	3	1	2	3	1	2	3					
Maize	1	5.71	5.71	1	3.64	3.64	2	3.64	7.28	2.67	-	-	4.5	23.8
Wheat	2	5.71	11.42	2	3.64	7.28	3	3.64	10.92		3.06	5.5	-	38.18
Total	3		17.13	3		10.92	5		18.2	2.67	3.06	5.5	4.5	61.98

1 - No. of operation 2 - Hour/hectare/operation 3 - Total hour * - (Assumed) if planter is used.

Table 6. Requirements of Tractor Drawn Implements for Hills

Implements	hour/ year	Life years*	Area (ha)	Expected requirement of working hours	Implements required number
Cultivator	208	12	100	1820	8-9
Disc Harrow	167	15	100	1092	6-7
Disc Plough	167	15	100	1713	10
Seed drill	80	15	75	229.5	3
Maize Planter	80	15	75	222.25	2-3
Trailer	333	15	-	2698	8
Wheat Thresher**	150	10	75	412.5	2-3
Maize Sheller**	150	10	75	337.5	2

* Kepner et. al., 1987. ** Hour/year & life of implements was assumed.

ii) the requirement of trailer in a year is almost the same as the tractor required for transportation i.e., 2699 h.

iii) the requirement of working-h/ha for maize planter and seed drill is 2.67 and 3.06, respectively.

iv) the requirement of working-h/ha for thresher and sheller is 5.5 and 4.5, respectively.

Presently seven tractors have been constantly engaged in crop production area of 73 ha at the farm. As per above calculation it needs about 10 tractors at the farm. This means that 3 more tractors should be engaged to fully control the total cropped area. The requirement of tractor-drawn matching equipment for the whole area should also be increased accordingly.

Conclusion

The following conclusions can be drawn from this study:

i) The requirement of tractor-hour is greater in the hills than in the plains for agricultural purposes.

ii) Ploughing needs maximum utilization of tractor followed by land developments and transportation.

iii) The study also focuses on full utilisation of tractor in the hills, it should be engaged for land developmental works.

iv) Tractor having less turning radius should be preferred.

v) For managing 100 ha farm in hills, the requirement of prime mover (tractor) should be nearly 14 with adequate matching equipments.

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Development of a Power-operated Rotary Screen Cleaner-cum-Grader for Cumin Seeds

by

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Abstract

In order to reduce the drudgery of manual cleaning, a mechanical rotary double screen cleaner-cum-grader suitable for cumin seed was designed and developed. The machine performed successfully with a cleaning efficiency above 80% when operated at 11 rpm screen speed, 5-7% screen slope and 30-50 kg/hr feed rate.

Introduction

India is the largest producer and consumer of cumin seed. Over 70 spices of cumin are grown in India. For 1994-95, the total area planted to cumin was about 3.25 lakh ha producing about 1.45 lakh tonne.

An estimate shows that the cumin seeds received at the marketing yard from the farmers contain an average of 20-25% impurities. Thus a low cost and medium capacity power-operated equipment suitable for cleaning and grading the cumin seeds, particularly at the traders level is felt wanting. In the past, some research on cleaner-cum-grader of different seeds has been done. Brewar et al (1982) attempted to develop a 100-kg per hour capacity hand-operated grain cleaner. Kachru et al (1990) tested a medium capacity pedal-cum-power-operated grain cleaner for various seeds. Hall (1991) measured the cleaner response for different parameters. Vishvanathan et al; (1994) developed a rotary sieve type cleaner-cum-grader suitable for small size impurities.

Design of Components

Dynamics of Rotary Cleaner

In a cleaner-cum-grader, grain mix from one end to another end is due to internal pressure force developed during the rotation of the grain mass or to the inclination of the cylinder. The grains are in contact with only a part of the cylindrical surface and have no relative velocity during their lift. **Figure 1** shows the force acting on a grain in a rotating cylinder. The critical angular velocity of a cylindrical sieve at which grains do not slide and, consequently, the sieving of fine particles ceases

$$Wcr = \sqrt{g/(r\sin\phi)} \quad (1)$$

The actual velocity of the cylindrical sieve must be less than critical, that is

Wact < Wcr

Speed of rotation of cylinder is:

$$n < \frac{30}{\Pi}\sqrt{g/(r\sin\phi)} \quad (2)$$

Feeding Device

A pyramidal shape hopper to hold the cumin seeds for up to 15-minute operation was designed. The holding capacity of a hopper required for 75kg/hr set up would be around 19kg. As the average bulk density of the cumin seeds at nominal moisture content is about 450kg/m^3, the volume of the hopper would be 0.042m^3. A sliding type feed regulating arrangement was also provided at the bottom of the hopper.

Screen Cylinder

A filled up portion of a screen cylinder is shown in **Figure 2**. The design of the screen cylinder was based on the time taken by the screen to move from feed end to the discharge end. The angle of the seeds inside the cylinder at rest are calculated by the equation:

$$\theta n + 1 = \theta n - \frac{\theta n(1-(\cos\theta n)/2)}{(3\theta n)/(2-(1+(\cos\theta n)/2))} \quad (3)$$

Driving and Power Transmission

A 1hp, 1440 rpm single phase electrical motor was used as prime-mover for the equipment. The size of the motor was decided after preliminary functional requirement of the operation at rated capacity. To evaluate the effects of the speed of the screen cylinder on the performance of the machine, pulleys of

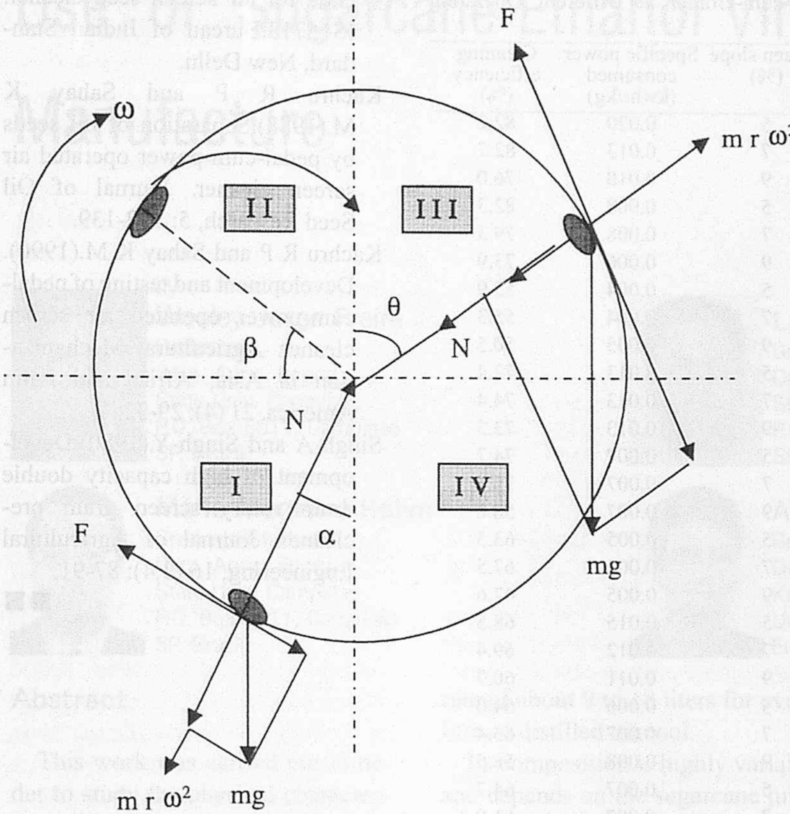

Fig.1 Force acting on a grain in a rotating cylinder.

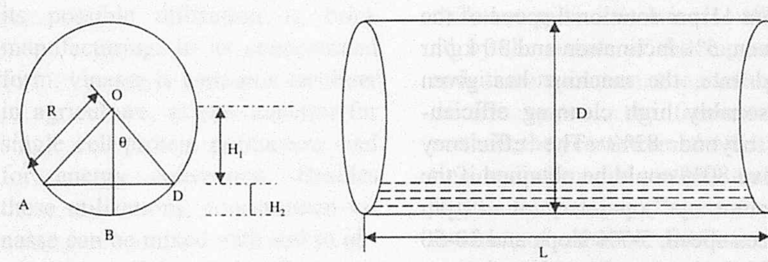

Fig.2 Filled up portion in the screen cylinder.

different sizes were used after the gear box.

Construction and Operation

The machine consists of a feeding device, screen cylinder, drive and power transmission. A pyramid shape hopper with 400 × 440 mm top was fabricated. A sliding gate type feed regulating valve was fitted at the lower end of the hopper. Two galvanised-iron wire-mesh screen with a mesh opening of 0.495 and 0.392mm, respectively, were rolled to make an inner and outer screen. A provision to mount the pulley was also made on the drive end of the shaft. A worm type foot mounted speed reducing gear box with 1:30 speed reduction was fitted with relevant V-pulleys for further power transmission.

Variety MC-43 of cumin seeds were used as test sample. The machine efficiency was evaluated at 7.5% moisture content (d.b.), feed rates (30, 50, 70 kg/hr), screen cylinder speed (11, 20, 28 rpm) and screen slope (5,7,9%). The cleaning efficiency of the machine was determined by using the following equation:

$$E = \frac{(m_f - m_u)(m_o - m_f)m_o(1 - m_u)}{(m_o - m_u)^2(1 - m_f)m_f} \quad (4)$$

where;

m_f is the mass fraction of material in feed

m_o is the mass fraction of material in overflow

m_u is the mass fraction of material in underflow

The specific power consumed by the machine was computed by the following equation;

$$P = \frac{(f - i) \times 3600}{t \times F \times E} \quad (5)$$

where;

p is the specific power consumed in kwhr/kg seed cleaned;

f is the final energy meter reading for cleaning the sample in kw;

i is the initial energy meter reading at start of cleaning in kw;

t is the machine operating time for cleaning the sample in sec;

F is the feed rate to the machine in kg/hr and

E is the cleaning efficiency of the machine in percent

Results and Discussion

The performance studies on the machine developed as cleaner-cum-grader for cumin seeds in terms of its cleaning efficiency were carried out with reference to different operating parameters. **Table 1** shows different values of cleaning efficiency as influenced by the speed of screen cylinders, feed rate to the screen and screen slope.

The data from **Table 1** indicate that as the slope of the screen cylinder with respect to horizontal increased, there was a reduction in the cleaning efficiency at all the feed rates to the machine and at all the speeds of the screen cylinder. This might be due to the possible reduction in the residence time the seed gets inside the screen at in-

Table 1. Performance Data of the Cleaner-cum-Grader at Different Operating Conditions

Expt.No	Screen speed (rpm)	Feed rate (kg/hr)	Screen slope (%)	Specific power consumed (kwhr/kg)	Cleaning efficiency (%)
1	11	30	5	0.020	82.2
2	11	30	7	0.013	82.7
3	11	30	9	0.010	76.0
4	11	50	5	0.008	82.3
5	11	50	7	0.008	79.3
6	11	50	9	0.006	73.9
7	11	70	5	0.004	55.9
8	11	70	7	0.004	55.3
9	11	70	9	0.005	50.5
10	20	30	5	0.013	72.4
11	20	30	7	0.013	74.4
12	20	30	9	0.013	73.5
13	20	50	5	0.007	74.7
14	20	50	7	0.007	75.4
15	20	50	9	0.007	58.8
16	20	70	5	0.005	63.5
17	20	70	7	0.004	67.5
18	20	70	9	0.005	47.6
19	28	30	5	0.015	68.5
20	28	30	7	0.012	69.4
21	28	30	9	0.011	60.7
22	28	50	5	0.006	64.0
23	28	50	7	0.007	63.4
24	28	50	9	0.008	58.5
25	28	70	5	0.007	64.7
26	28	70	7	0.007	51.0
27	28	70	9	0.008	43.5

creased screen cylinder slope. For the feed rate of 70 kg/hr the cleaning efficiency was lower than 60% for all screen slopes which was further reduced to lower than 50% at the combination of higher slope and higher speed of the screen cylinder.

As the feed rate to the machine increased from 30 to 50 kg/hr the cleaning efficiency was reduced slightly. Thereafter on further increase the feed rate up to 70 kg/hr, there was sharp reduction in the cleaning efficiency of the machine. The phenomena of the clustering of the seeds inside the screen cylinder at high feed rate might reduce the contact area and time between the seeds and screen thereby affecting adversely the cleaning performance.

For obtaining higher cleaning efficiency and, therefore, more pure grades, the machine should be operated at slow speed and at low inclination of screen cylinder with respect to horizontal while maintaining a controlled feed rate. At about 11rpm rotational speed of the screen, 5% inclination and 30 kg/hr feed rate, the machine has given reasonably high cleaning efficiency beyond 82%. The efficiency above 80% could be obtained if the machine is operated at 11rpm screen speed, 5-7% slope and 30-50 kg/hr feed rate.

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Use of Sugarcane Ethanol Vinasse for Brick Manufacture

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Abstract

This work was carried out in order to study the physical characteristics of *vinasse* effluent from sugarcane ethanol production and its possible utilization in brick manufacturing. In its concentrated form, vinasse is used as a fertilizer in agriculture, as raw material for single cell protein production, and for energy conversion. Besides these utilizations, concentrated vinasse can be mixed with soil to obtain a material called soil-vinasse whose physical and mechanical characteristics allow the production of non-structural air-dried bricks. Compressive strengths of 1.92 and 1.79 MPa were reached by brick manufactured with sandy and clayey soils, respectively, treated with a 12% dosage of a 19% solids concentrated vinasse.

Considerations on Vinasse Problems and Potentials

The vinasse resulting from sugarcane ethanol production is the main effluent from ethanol distilleries in Brazil. It is produced at the rate of about 9 to 18 liters for every litre of distilled ethanol.

Its composition is highly variable and depends on the sugarcane juice quality and substrate type such as molasses, sugarcane juice, or mixed molasses and juices. It is also affected by the nature of the sugarcane and its composition, the mash production system, the fermentation method, the yeast strain, the distillation equipment and method, and the *flegma* composition (flegma is a by-product of ethanol distillation; it contains 50% ethanol and it is obtained from the top of the first distillation column from which the resulting residue is vinasse).

Because of its organic load, vinasse possesses a high B.O.D. (biochemical oxygen demand) ranging from 16,000 to 30,000 mg/l (Leme et al. 1979, INT 1978), so it is a powerful pollutant. Its disposal into lakes, rivers, and canals always causes an acute lack of available oxygen in the water. Therefore, the stabilization of vinasse as well as its use must be carried out in such a way that no damage to the environment can be caused.

Although vinasse is classified as a pollutant residue, it is biodegradable, water soluble, not inflammable, non-reactive and non-pathogenic characteristics lead COPERSUCAR (The Cooperative of Cane, Sugar and Alcohol Producers in the State of São Paulo) to classify it as a "non-dangerous residue". Nowadays, controlled application of vinasse to the soil is a very safe technique which does not result in groundwater contamination.

In its original form or as a concentrate, vinasse can be used as a fertilizer in agriculture, as raw material in the fermentative manufacture of single cell protein for human and animal feed and other products, and as starting material for energy generation by biodigestion into biogas and by incineration (Cahmi 1979).

Worldwide, the use of vinasse from different distillery processes, such as of wheat starch ethanol (in Australia), dried grain vinasse (in the United States), sake vinasse (in Japan), corn distillery vinasse (in China), etc., is still a subject of research, specially related to animal feed, cultivation of microorganisms, production of protein poly-γ-glutamate, spraying on fields, soil amendment, etc.

Table 1. Main Characteristics of Utilized Soils

Parameters		Soils	
		Sandy soil	Clayey soil
Gradation (%, weight basis)	Coarse sand (0.42-2.00 mm)	4.0	5.0
	Fine sand (0.05-0.42 mm)	68.0	24.0
	Silt (0.005-0.05 mm)	11.0	14.0
	Clay (< 0.005 mm)	17.0	57.0
Physical test constants (%)	Liquid limit	15.3	40.3
	Plastic limit	14.4	32.5
	Plasticity index	0.9	7.8
Soil classification	AASHTO	$A_{2\text{-}4(0)}$	$A_{7\text{-}5(8)}$
	Bureau of Public Roads	Sandy	Clayey
Chemical characteristics	pH (in $CaCl_2$)	4.40	6.30
	Organic material (%)	1.60	1.50

Table 2. Apparent Dry Maximum Specific Weight (γ_{max}) and Optimum Humidity (W_o) From Soil-concentrated Vinasse Compaction Test (Rolim and Freire 1996)

Parameter		Concentrated vinasse dosages applied to sand-clayey soil				Concentrated vinasse dosages applied to clay-silty soil			
		0%	12%	16%	20%	0%	12%	16%	20%
γ_{max} (kg/dm^3)	A	1.9	1.9	2.0	1.9	1.5	1.6	1.6	1.6
	B	1.9	1.9	2.0	1.9	1.5	1.6	1.5	1.5
	C	1.9	2.0	1.9	2.0	1.5	1.6	1.6	1.6
	X	1.9	1.9	2.0	1.9	1.5	1.6	1.6	1.6
w_o (%)	A	10.69	9.52	8.93	8.66	27.06	26.45	24.14	23.95
	B	11.08	9.31	8.75	9.27	26.64	26.45	25.36	24.65
	C	10.41	9.18	9.26	9.18	27.04	26.45	24.72	24.30
	X	10.73	9.34	8.98	9.04	26.91	26.45	24.74	24.30

A,B,C = replications; X = average.

Table 3. Compressive Strength of Cylindrical Soil-concentrated Vinasse Specimens, MPa (Rolim and Freire 1996)

Age		Concentrated vinasse dosages applied to sand-clayey soil				Concentrated vinasse dosages applied to clay-silty soil			
		0%	12%	16%	20%	0%	12%	16%	20%
7 d	A	1.48	2.16	2.57	2.46	1.61	2.12	2.25	1.77
	B	1.41	2.11	2.41	2.54	1.35	2.57	2.73	1.93
	C	1.41	2.06	2.64	2.50	1.19	2.25	2.09	1.77
	X	1.43	2.11	2.54	2.50	1.38	2.31	2.36	1.82
30 d	A		2.90	2.99	3.12		1.93	2.25	1.90
	B		3.02	3.22	2.99		1.74	2.38	1.77
	C		2.73	3.15	3.06		2.25	2.25	1.03
	X	1.43	2.88	3.12	3.06	1.38	1.97	2.29	1.57
90 d	A		2.60	3.12	3.22		2.25	1.99	2.28
	B		2.57	3.15	3.34		1.65	1.93	2.57
	C		2.67	2.80	3.38		2.03	1.70	2.35
	X	1.43	2.61	3.02	3.31	1.38	1.98	1.87	2.40

A,B,C = replications; X = average.

Vinasse from sugarcane ethanol is currently used in Brazil for a number of purposes such as fertilized irrigation of cane fields using flooding irrigation systems, furrow irrigation, sprinkling with semi-fixed equipment, and big gun sprinkling irrigation (Orlando Filho et al.1983); fertilizing other crops, such as grain sorghum (***Sorghum bicolor*** *L.*) (Sengik et al.1996); organic matter separation producing high value industrial products (glycerin, lactic and succinic acids, and tannin) (Rotenberg et al.1979); production of biomass from yeasts such as ***Candida spp*** (Martelli and Sousa 1978) and production of fungi biomass from species such as ***Aspergillus oryzae, Torula utilis***, etc. (DAF 1977); and as animal feed (Pedutti Filho and Zezza Neto 1977).

Some measures can be taken to increase the total content of solids in the vinasse with consequent nutrient concentration and so contributing to reduce costs of applying the vinasse using the "fertirrigation" procedure (Glória and Orlando Filho 1984).

The Soil-vinasse Material

Almeida et al. (1950) were the first researchers to report the chemical composition of "in natura" vinasse. The results showed that "in natura" vinasse contains more than 93% of water, 5% of organic matter, and the remaining of its composition represented by mineral constituents. In the later, potassium is the predominant element, reaching as much as 2/3 of the total.

The technology for vinasse concentration, understood as the increase of total solids, was first developed in Austria after World War II, as an imperative to improve the residue utilization (Zezza Neto, 1977).

First attempts to use vinasse in combination with different soil types to produce alternative construction material have been carried out recently in Brazil by Aguiar (1992). Working with two different soils, one sand-clayey soil and one clay-silty soil, the author applied different and increasing percentages of concentrated vinasse containing 30% solids to evaluate its effect on physico-mechanical characteristics of the soil. The concentrated vinasse was obtained by using an industrial evaporator. Laboratory tests showed that the concentrated vinasse treatments could promote a significant increase in the mechanical strength in compression, after 7 days, when compared with the reference treatment with no addition of vinasse. In sand-clayey soils, 22% vinasse increased the mechanical strength to 2.37 MPa compared with 1.40 MPa of the reference treatment. In clay-silty soil, 22% vinasse increased the mechanical resistance of the soil to 4.82 MPa compared with 1.40 MPa of the reference.

Table 4. Compressive Resistance of Bricks Moulded with Soil and 12% Concentrated Vinasse

Specimens	Compressive resistance (MPa)	
	Sandy soil	Clayey soil
1	2.11	1.45
2	2.02	1.55
3	1.92	1.71
4	1.90	1.96
5	1.76	1,80
6	1.67	1.71
7	1.90	1.86
8	1.65	2.00
9	1.78	1.88
10	1.86	1.96
11	2.13	1.65
12	2.05	2.00
13	2.00	1.96
14	1.65	1.61
15	2.13	1.45
16	2.11	2.09
Average	1.92	1.79
Deviation	0.17	0.21
Standard deviation (%)	9.01	11.52

Preliminary Essays

The physico-mechanical characteristics of soil-concentrated vinasse mixtures and their use in air-dried brick fabrication were investigated. Two different soil types, a sandy soil and a clayey one, with different additions (0%, 12%, 16%, and 20%) of a 19% solids concentrated vinasse, were tested, being the main characteristics of both soils shown in **Table 1**. All the experiments were made with three replications.

The soil-concentrated vinasse samples were submitted to Proctor compaction tests and the results obtained are presented in **Table 2**. The statistical analysis of the data indicated that there was no significant difference at the 5% level of significance for samples with different dosages of concentrated vinasse.

Cylindrical specimens made with soil-concentrated vinasse mixtures were moulded and cured for periods of 7, 30, and 90 days, and then subjected to unconfined compression tests. The results are presented in **Table 3**. Treatment of the two soils with concentrated vinasse increased its strength in unconfined compression with respect to the reference, for all ages independently of the applied dosage. On average, the 12% concentrated vinasse dosage applied to the studied sandy and clayey soils was statistically equal to the other vinasse dosages, all of which were higher than the reference (0% vinasse).

Laboratory Tests of Soil–concentrated Vinasse Bricks

In overall terms, the 12% dosage of concentrated vinasse presented the best results and was selected for brick moulding. After screening with a mesh number 4 (4.76 mm hole width) and controlling moulding moisture, the soil-vinasse mixtures were pressed in a conventional manually-operated brick machine. The bricks were carefully removed from the machine, stocked and left to dry for 30 days when they were submitted to compression tests according to the standards.

Sixteen bricks of each soil were broken under compression being the data presented in **Table 4**. The results indicated, for the soil-concentrated vinasse bricks made with sandy soil, an average strength value equal to 1.92 ± 0.17 MPa, with a standard deviation of 9.01%; for the bricks made with clayey soil, the average strength was 1.79 ± 0.21 MPa and the standard deviation of 11.52%.

Although the bricks made from sandy soil present higher average values for mechanical resistance to compression than the ones prepared with clayey soil, the differences were not statistically significant at the 5% level of significance.

However, the bricks manufactured with sandy soil treated with 12% of concentrated vinasse demonstrated better workability, being easier to mould and remove from the mould than the bricks manufactured with clayey soil, which presented a great difficulty in moulding, especially with regard to moisture control and removal from the mould.

Air-dried brick manufacturing with soil-concentrated vinasse proves a technically viable option having some advantages over the conventional ceramic bricks because burning is not required and a liquid residue produced in large quantities by the alcohol distilleries in Brazil is utilized (170 million of vinasse in the 1997/1998 harvest).

Conclusions and Recommendations

Large quantities of vinasse are produced in Brazil. Technique developed to reduce costs of vinasse disposal and attempts to find new methods of vinasse utilization are, therefore, looked into with great interest.

Soil-vinasse, a soil treated with vinasse, is a mixed material that presents a good physical and mechanical behavior. High compressive strength values of cylindrical soil-concentrated vinasse specimens were reached with increasing dosages of a 19% solids concentrated vinasse applied to either a sandy and a clayey soil subjected to 7, 30, and 90 days aging periods.

Air-dried bricks manufactured with two different soil types treated with 12% of concentrated vinasse presented good results when submitted to compressive tests. However, such bricks are not recommended for use in saturated water conditions because they collapse due to its high water absorption capacity. For this reason, the use of such bricks is recommended in the open air, following treatment with impermeable products, or under sheltered conditions.

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Performance of State-owned Tractor Hiring Units in Nigeria:

A Case Study from Taraba State

by

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Abstract

This paper presents the findings of a survey of agricultural machinery and mechanization activities at the Taraba State Tractor Hiring Unit in Nigeria. The unit had a total of 97 tractors, 77 disc ploughs, 48 disc harrows and 16 trailers, of which only 49.5%, 54.5%, 60.4% and 18.8%, respectively, were functional. Other implements found were seed planters, boom sprayers and disc ridgers. However, none of these was operational. As a result, farm mechanization in the state is merely skeletal, being restricted only to disc ploughing and disc harrowing. Generally, the tractors and implements do not serve up to their expected life-span. The main reasons for early failure were identified as poorly developed farmlands, rough handling of tractors and implements, and negligence to regular maintenance. Also, there were great delays to repairing due to lack of funds and replacement parts, as well as poor workshop facilities. The article proffers some solutions that could help to minimize these problems.

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Introduction

Nigeria is predominantly an agricultural country with a land mass of 98.3 million hectares of which 72% is considered suitable for agricultural production (Makanjuola et al, 1991). However, the rate of growth in food production in the country is very slow - about 2.5% per annum (Okigbo, 1991). One of the main reasons for this is the low level of agricultural mechanization in the country. For instance, the FAO (1996) estimated that Nigeria had a total of only 11,900 tractors in 1996. This is clearly an inadequate number, considering the high percentages of the agricultural population and arable land in the country. The contribution of engine power in overall agricultural production is only 2%, compared to 8% and 90% from animal and human power, respectively, (Anazodo et al, 1989 as cited by Odigboh and Onwualu, 1994). This is despite the fact that at various times since Nigerian independence in 1960, quite a number of programmes and establishments have been set-up and ran. These include: Farm Settlement Schemes, Tractor Hiring Units (THUs), Operation Feed the Nation, Green Revolution, Tractor Assembly Plants, Agricultural Development Programmes, National Centre for Agricultural Mechanization and National Agricultural Land Development Authority (NALDA).

The history of the THU in the country can be traced as far back as 1956 when the administration of the defunct Northern Region established a THU, which did some ploughing for farmers at a nominal charge (Makanjuola et al, 1991). After independence, similar THUs were established in other states to provide tractors and implements to farmers at subsidized rates in order to boost agricultural production in the country. Many state governments still retain these tractor hiring units under their ministries of agriculture, while others established autonomous agricultural mechanization authorities. The state-owned Taraba State THU was set up in 1976, when it was a part of the former Gongola State. The present-day THU came into existence with the creation of the Taraba State in 1991. The unit is divided into 12 sub-units, which also represent the local government areas (LGAs) in the state. Taraba has a total land area of 5,937,812 ha, of which about 67% is arable (Dickson, 1994). The major crops grown in the state are sorghum, maize, rice, millet, beans, groundnut, cotton, yam, cassava and sweet potatoes. The fertile arable lands in the state, made of diverse soil types (sandy loam to clay), coupled with the favourable climatic conditions (e.g., 1350 mm of average annual rainfall), make production of large quantities of these crops conducive. One of the essential inputs required to realise this level of food production is a relevant, sufficient and reliable fleet of agricultural machinery. The objective of this study was to assess the status of farm tractors and implements in the Taraba state THU vis-à-vis their numbers, functional conditions and problems related to their use.

Table 1. Makes and Models of Tractors Available in the Taraba State THU

Tractor make and model	No. available
Steyr 768	35
Steyr 8073	15
Steyr 8075	19
Fiat 8066	15
Ford 6610	9
Farmwell 480	2
Case International 685	2
Total	97

Table 2. Types and Makes of Implements in the Taraba State THU

Type of implement	Make	No. available
Disc plough	Baldan	32
	Galucho	20
	Parmiter	25
Disc harrow	Baldan	22
	Galucho	5
	Parmiter	18
	Farmwell	3
Disc ridger	Parmiter	6
Seed planter	Parmiter	2
Boom sprayer	Parmiter	2
Trailer	Galucho	3
	Parmiter	9
	Weeks	4
Total		151

Methodology

The study was conducted in all of the 12 sub-units of the Taraba State Tractor Hiring Unit. Information was sought from agents of the THU as well as from farmers whom services are rendered to. Data collected included number, type, make, model and conditions of tractors and implements. Also, information such as causes of machinery breakdown, delay in repairs and problems encountered in the unit was gathered. Simple analysis was used to evaluate the data.

Table 3. Availability and Conditions of Tractors in Different Sub-units of Taraba State THU

Sub-unit	Number by condition			Total
	F*	NF-R	NF-S	
Bali	5	2	2	9
Donga	6	1	1	8
Gashaka	2	2	2	6
Ibi	4	3	1	8
Jalingo	4	0	3	7
Karim Lamido	4	3	1	8
Lau	3	3	3	9
Gembu	4	7	4	15
Takum	5	3	2	10
Wukari	5	1	0	6
Yorro	4	1	0	5
Zing	2	4	0	6
Total (%)	48 (49.5)	30 (30.9)	19 (19.6)	97 (100)

*F: Functional, NF-R: Non-functional/repairable, NF-S: Non-functional/scrap.

Results and Discussion

The THU had a total of 97 tractors and 151 farm implements as of December, 1994. All the tractors were wheeled type and in the power range of 50 to 80 kW. There were five makes of tractors, with Steyr having the highest number of 69 tractors. **Table 1** shows the various tractor makes and models belonging to the THU. Six types of implements consisting of three makes of disc ploughs, four makes of disc harrows, three makes of trailers, and one make each of disc ridger, seed planter and boom sprayer were identified (**Table 2**).

The distribution of tractors and implements among the different sub-units is shown in **Tables 3** and 4. These tables show that tractors were distributed more evenly than implements among the areas. Of the 97 tractors found in the unit, 49.5% were functional, 30.9% non-functional but repairable and 19.6% scrap (**Table 3**). The composition of unusable tractors (50.5%) outweighs, by far, the estimate of 30% quoted by the FAO (1992). From the 151 implements available, 49% were functional, 29.8% non-functional but repairable and 21.2% scrap (**Table 4**). None of the disc ridgers, seed planters and boom sprayers was functional at the time of this survey. An instance whereby less than half each of the total number of tractors and some selected implements are functioning in an agricultural mechanization agency cannot be claimed to be a success story. Under normal circumstances, tractors and agricultural field implements are supposed to last at least 10 years, if proper care is tak-

Table 4. Availability and Conditions of Farm Implements in Different Sub-units of the Taraba State THU

Sub-unit	Type of implement	No. by condition			Total
		F*	NF-R	NF-S	
Bali	Disc plough	3	1	0	4
	Disc harrow	1	1	0	2
Donga	Disc plough	4	2	0	6
	Disc harrow	6	0	0	6
Gashaka	Disc plough	3	1	2	6
	Disc harrow	0	1	0	1
Ibi	Disc plough	2	0	1	3
	Disc harrow	1	1	1	3
	Disc ridger	0	1	0	1
	Seed planter	0	1	0	1
	Boom sprayer	0	1	0	1
Jalingo	Disc plough	4	2	2	8
	Disc harrow	2	2	0	4
	Trailer	1	0	0	1
Karim Lamido	Disc plough	2	0	1	3
	Disc harrow	1	1	1	3
	Disc ridger	0	1	0	1
	Seed planter	0	1	0	1
	Boom sprayer	0	1	0	1
Lau	Disc plough	5	0	0	5
	Disc harrow	7	1	0	8
	Trailer	0	7	0	7
Gembu	Disc plough	8	2	15	25
	Disc harrow	2	2	2	6
	Disc ridger	0	0	4	4
	Trailer	2	6	0	8
Takum	Disc plough	5	5	0	10
	Disc harrow	4	4	0	8
Wukari	Disc plough	2	0	0	2
	Disc harrow	1	0	0	1
Yorro	Disc plough	2	0	0	2
	Disc harrow	3	0	0	3
Zing	Disc plough	2	0	1	3
	Disc harrow	1	0	2	3
Total (%)		74 (49)	45 (29.8)	32 (21.2)	151 (100)

* F: Functional, NF-R: Non-functional/repairable, NF-S: Non-functional/scrap

en in maintaining and using them (Culpin, 1975). It has been found that some of the tractors and implements did not even serve up to five years before they became scrap or non-functional. Because many of the implements were unusable, the THU could carry out only two operations, namely; disc ploughing and disc harrowing. This meant that even the functional tractors were under-utilised. They were mainly used for about two months during the soil preparation stage at the onset of the rainy season, a time when farmers scramble for this skeletal service. The trend is similar to the findings of a study conducted in a neighbouring state (Umar, 1997). This is an unhealthy situation. Without mechanizing various operations, the THUs cannot exploit the full potential of their farm machinery and achieve some of the coveted goals for which they were established. The situation does not seem to change from what it used to be almost a decade ago, when it was reported that THUs in Nigeria did not make any significant impact to achieve their set objectives (Sangodoyin and Ogedengbe 1987; Mafari, 1988; Makanjuola et al, 1991). The main problem that haunts the THU is lack of prompt repairs and due maintenance of its machinery. For instance, it has been gathered that once a tractor needs a major repair, it may not be back to normal operation at all or for quite a long time, mainly due to lack of funds and/or replacement parts. Workshops are not well-equipped to ensure hitch-free services. This picture is similar to the findings of Babatunde (1996) in a study carried out in some other states in Nigeria. A rarely considered (though important) problem that might complicate the dearth of replacement parts, in general, could be the diversity of makes and models of tractors and implements. Any proliferation of machinery makes and models renders it severely more difficult to acquire replacement parts. Apart from the need to retrain mechanics to handle motleys of machines, special orders for scarce components might have to be placed (at high costs) and a lot of time would be wasted in waiting for their arrival.

The main reasons for early failure of tractors and implements in the unit are poorly developed farmlands, rough handling of tractors and implements and negligence to regular maintenance. Farmlands in Taraba are characterized by obstructions such as trees, stumps and roots, as the state lies within the Savannah vegetation zone of Nigeria. Thus, tillage implements are especially prone to high rates of breakdown. The scenery in some LGAs like Gembu, Takum, Zing and Yorro is hilly and rocky. This kind of terrain requires appropriate land clearing equipment, which is completely lacking and, consequently, tractors and implements are suffering accordingly. Farmers still employ the age-old methods of extending their farmlands or establishing new ones by using manual implements or by burning bushes and trees, a situation which jeopardises the environment further. It is hoped that the recently established National Agricultural Land Development Authority (NALDA) would be of great assistance to farmers in developing their lands.

Reckless handling of tractors and implements (e.g., excessive speeding) by some operators, due to their sheer indifference to duty or because they are half-baked, hastens the demise of the capital-intensive farm machinery in Taraba state (and presumably in many other states in Nigeria). Optimum speeds of tractors performing various field operations need to be observed and some extra care taken due to the rough terrain and obstructive topsoil conditions. Therefore, tractor operators and mechanics need to undergo formal training on the basics of their trade to ensure proper handling of farm machinery. There is also the need to instil more sanity within the system as a whole. The Unit could and should be able to sustain itself with revenues collected from the farmers for its services. To achieve this, there is need to properly remunerate the staff to improve their commitment to duty and transparency.

The THU should also have an appropriate repair and maintenance culture to attain reasonable lifespans of tractors and implements so that premature wastage of assets could be minimized. At the present time, regular maintenance is not strictly adhered to and replacement parts are sometimes scouted for, only when the need for them arises. This affects the timeliness of field activities, which can translate into reduced farm yields. The functional tractors and implements are too few to satisfy the needs of most farmers in this largely agricultural state. Considering the fact that private participation in agricultural mechanization in the state is negligible, and that there is no sign that it will improve in the near future due to high costs of farm machinery, it is necessary for the state government to rehabilitate the repairable tractors and implements in order to uplift its usable farm machinery and, consequently, boost agricultural production in the state.

Conclusions

Farm tractors and implements at the Taraba State THU are very few and a high percentage of them is non-functional. Several factors have been identified for early breakdown of farm machinery in the unit and delays in repairs. At the present time, the THU renders services mainly for disc ploughing and disc harrowing, which in any case, are not comprehensive across the state. The government, therefore, should strive to mechanize other operations, rehabilitate the repairable tractors and implements and buy more, when possible, to satisfy the huge demand for them by farmers. It is also necessary to ensure a good stock of genuine replacement parts, to upgrade the workshop facilities and to imbibe preventive maintenance culture. Finally, the unit needs across-the-board reorientation to make its staff more dedicated and responsible to duty.

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Scope of Farm Mechanization in Shivalik Hills of India

by

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Abstract

Himachal Pradesh is a hilly state which provides favourable environment for raising almost all types of agricultural and horticultural crops due to widely varied micro-agro-climatic regions of the state. But the farm mechanization in the state is very poor in terms of mechanical power, efficient implements, land reclamation, water management, renewable energy and post harvest activities. The mechanization is badly hampered by stepped, small and irregular fields, undulating topography, lack of adequate agricultural engineers and skilled manpower, poor facilities of repair, maintenance and manufacture of implements and high cost solar gadgets. The immediate attention of the state government and other funding agencies is required to strengthen the agricultural wing in the Himachal Pradesh by creating strong cell of agricultural engineering to handle farm mechanization problems more efficiently. Despite various limitations and constraints, there is a great scope to increase productivity of land and farmers economy by creating small water resources for increasing irrigated areas, land development, use of efficient farm power and implements, harnessing more rainwater, disseminating renewable energy gadgets and introducing small scale agro-based industries employing post harvest engineering principles.

Introduction

The major parts of Himachal Pradesh (H.P.) lies in Shivalik hills of India which is situated between 30.3 and 33.3^0 North Latitude and 75.3 - 79.0^0 East longitude. Himachal Pradesh was born after independence. The state is broadly classified into four agro-climatic zones viz. sub-mountain low hills sub-tropic zones (365-650 m above m.s.l), mid hills sub-mountain zone (651-1800 m above m.s.l), high hill temperate wet zone (1801-2200 m above m.s.l) and high hills temperate dry zone(>2201 m above m.s.l). Each agro-climatic zone can be further divided into various micro-agro-climatic zones due to great variation in slope, topography, soil and water availability. Numerous micro-agro-climatic zones provide suitable environment to raise almost all types of agricultural and horticultural crops in the state. Area under different agro-climatic-zones of H.P is given in **Table 1** which reflects the status of major cropping sequences and irrigated area.

The state receives 1664.2 mm average annual rainfall and comprises a geographical area of 5567.3 thousand hectares which is only about 1.7% of total geographical area of India. The rainfall distribution pattern varies greatly in time and space. The higher reaches of

Table 1. Area under Different Agro-climatic Zones of H. P.

Particular	Agro-climatic Zones I	II	III	IV
Geographical area, (000, ha)	913.0	1183.2	1280.9	2190.0
Cropped area, (000, ha)	355.1	383.4	171.8	24.0
Elevation, m (above m.s.l.)	<650	651-1800	1801-2200	>2201
Major cropping sequences	Wheat-Maize	Wheat-Maize	Wheat-Maize	Barley/ Wheat-Maize
Percent of cropped area covered	42-33.91	27.5-24.1	38.4-33.4	19.6/15.8-7.1
Percent of irrigated Area	16.6	17.3	7.8	40.6

Source: Singh, M., Rao, S. N., Jain, T.C., Bhatanagar, O. p., Kingra, I. S. and Rana, R. S. 1982. NARP Report of ICAR Research Review Committee for HPKV, Palampur. Published by ICAR, Krishi Bhawan, New Delhi- 110001.

Kangra district receive as high as 2500 mm rainfall whereas the cold desert area of Lahaul and Spiti (>2472 m above m.s.l) receives only 10 mm rainfall. The total population in the state is 51.7 lakh with 8.44 lakh land holdings. The area-wise classification of available land of the state is given in **Table 2** indicating that only 11.27% area is utilized for crops and the remaining areas are for forest, permanent pasture, follow land etc. The operational landholding and the percentage distribution of area operated by major size groups of H.P. are presented in **Table 3**. The average size of operated land holding in H.P. is 1.21 ha which is 28% less than average operated holding size in India. The fragmentation of landholding is expected to be greater, especially under small and marginal farmers categories in the state.

There is abundance of water in the state received through precipitation (snowfall and rainfall) but the major portion goes to waste and being utilized in the lower states. Only a very small fraction of state water is being used in the state and farmers are deprived of irrigation and domestic water availability. Similarly, the state has abundance of natural energy sources like sunshine, wind, vegetation, water flow and other biological wastes which are not harnessed properly for their use, resulting in very low energy consumption per capita, de-forestration and poor health. The post-harvest losses, poor marketing and sticking to traditional farming system are restricting farmers to use improved inputs.

The crops raised in the state and their production are given in **Table 4**. Although, there has been a general increase in the average yield of important crops during the preceding years, the increasing yield is not expected to meet the food grain requirements of the increasing population.

It was focused at national level in 1988-89 that apart from the use of high yielding varieties and commercial fertilizers mechanization plays an important role in increasing agricultural productivity which is more relevant in HP. The key factors in improving agricultural productivity are timeliness and efficient energy inputs to various farm operations. There is a great scope of farm mechanization in hill agriculture system development and adoption of appropriate engineering-based technology in farm power, farm implement, land and irrigation development; renewable energy sources and post harvest activities. This paper describes the present level of farm mechanization in the state with special reference to its potential and limitations.

Table 2. Land use in Himachal

Classification	Area, (000, ha)	Area, (000, ha) in India
Total geographical	5567.3	328759
Forest	1034.6	-
Gross cropped	983.6	-
Net sown area	627.5	140149
Permanent pasture and other gross land	1150.6	-
Land under misc. trees & crops	48.1	-
Fallow land	116.0	-
Irrigated	125	50100

Source: Statistical Abstract, India (1990), H.P. Agricultural Hand book (1990),. Statistical outline of H.P. (1995), FAO Year book (1996) and Glimpses of agriculture in Himachal Pradesh (1996).

Table 3. Operational holding and percentage distribution

Class	Size of holding	Percent Distribution operated		No. of operational holdings, (Lakh)		Average size of operation holding, (ha)	
		H.P	India	H.P	India	H.P	India
Marginal	<1 ha	21.3	13.18	5.32	567.48	0.4	0.38
Small	<1-2 ha	23.3	15.88	1.66	178.81	1.41	1.43
Semi- medium	2-4 ha	25.5	22.32	0.94	132.54	2.95	2.76
Medium	4-10 ha	20.3	28.68	0.36	79.20	5.73	5.94
Large	> 10 ha	9.6	20.24	0.055	19.25	17.58	17.20
Total		100.0	100.0	8.335	977.28	1.21	1.68

Source: Statistical Abstract, India (1990) and Statistical outline of H.P. 1995.

Adoption Level of Farm Mechanization

Farm Power, Tools and Implements

The use of improved farm implements is very low in the State as compared to many other states of India. The primitive nature of tools and implements are still being used by farmers for carrying out preparatory tillage operations, sowing, interculture and harvesting operations. The present status of farm implements/machines under use in HP is shown in **Table 5**.

It is clear from the table that sowing/planting is normally done by broadcasting/dropping seed behind plough manually which not only consume more labour but it adversely affects the crop stand resulting in poor yield. The iron (S. S) and indigenous (wooden) ploughs are being used in the preparation of seedbed and sowing. The clod breaking after opening land is a severe problem in some of the regions, particularly after harvest of paddy which is done by women with wooden hammer. This again

Table 4. Area and Production of Various Crops

Crop	Area, (10^3 ha)	Production, (10^3 mt)
Wheat	315.0	636.62
Maize	370.0	599.33
Rice	83.0	112.23
Pulses	61.0	28.5
Sugarcane	2.2	2.8
Oil seed	59.0	24.0
Potato	16.2	140.0
Spices (Turmeric, ginger, chillies, kalazira)	4.4	20.0
Vegetables (Peas, tomato, cocurbits, bean, onion, garlic, cabbage, cauliflower, etc.)	25.0	400.0
Apple	72.4	294.73
Nimbu variety	30.15	21.39
Akrot and dry fruit	14.55	2.21
Other fruits	65.2	7.14
Tea	3.2	1.2

Source: Glimpses of agriculture in Himachal Pradesh (1996).

Table 5. Agricultural Implements and Tools

Implements	Number
1. Wooden plough	528738
2. Iron plough	270469
3. Diesel engine	2358
4. Tractor	1319
5. Electric pump	934
6. Maize sheller	1037
7. Sprayer	11607
8. Thresher	8847
9. Bullock cart	4722
10.Cane crusher-electric/ bullock	1413

Source: Statistical outline of H.P. (1995).

Table 6. Distribution of Principal Livestock

Livestock	Number	
	H.P	India
Cattle	2173663	192453000
Yalk	3495	-
Buffalo	616415	69783000
Sheep	1090322	48765000
Goat	1059862	95255000
Horses and ponies	16670	916000
Others	33000	9914000
Total	4988540	369526000

Source: Statistical outline of H.P. (1995).

consumes more energy which is non-productive. Presently, some of the farmers are using plankers with knives for clod breaking in paddy fields for Rabi sowing. For weeding and interculture operations, the khunti (local name) is used by the majority of the farmers in the State. However, plant protection and threshing equipments are adopted by some of the medium sized and large categories of farmers. Bullocks and human are the main sources of farm power. Some of the medium sized and large farmers are using tractors for tillage operations in their fields as well as on custom-hiring to other farms. Very few farmers use power tillers except for field preparation only. For harvesting of crops and fodder grasses, farmers use plain sickles because of they are available at low cost.

Land and Water Management Practices

The State has 4 major rivers and a number of perennial streams. Besides its 1664.2 mm average annual rainfall, only 19.92% cropped area is brought under irrigation while the State has an exorbitant potential water for irrigation. Only 934 electric pump sets are used by the farmers for lifting water from surface stream and ground water. The most common method of irrigation is through kuhls (water diverted through open gravity channels from higher points of perennial stream) and its branches.

The precipitation in farm of snowfall and rainfall is many times greater than that of water requirement of the vegetation, including crops, forest, horticulture, pasture etc. A major part of the precipitation water flows down to other states like Uttar Pradesh, Haryana and Punjab through rivers and their tributaries. A lot of fertile soil is also carried away from the state through runoff water flowing through the rivers. Despite abundance of water sources in the State the availability of water for irrigation and domestic use to the farmers is very meagre due to undulated topography and poor availability of ground water aquifers. It is shocking to know that less than one-fifth of cultivable area in the State is irrigated and rest above 80% is just rainfed whereas the water going down to other state through streams and rivers are being used for irrigation in the lower States

The land is quite fragile, dissected into hills and vallies through numerous streams/gullies. The land slopes are very high and soil depth is very low in some places. The cultivated lands are on high slopes and in the form of terraced fields of very small sizes and irregular boundaries. The paddy fields are almost levelled into very small irregular shaped terraces. Conveyance of irrigation water through undulating topography to patchy agricultural fields is a complex problem. Small-sized fields, their irregular boundary and absence of field to field path restrict the use of tractors, power tillers, improved implements etc.

The whole region is under severe soil erosion due to high slopes, deforestation, road construction and traditional cultivation methods. The terraced lands are not properly developed for safe water disposal and irrigation.

Renewable Energy

The State government provides electricity to almost every village for lighting but for cooking meals and heating water, fuel wood is normally used by the farmers resulting in deforestation and degradation of land. As a result of special emphasis by the government through several schemes in the last decade some farmers in the State have adopted renewable energy sources for meeting their domestic energy requirements. Some 37,400 fixed dome type biogas plants of different sizes (1 m^3 to 6 m^3) have been installed in lower and upper Shivalik hills (10 districts out of 12 in the sate) since 1981. A survey on biogas plant shows more than 60% functionality. No biogas plants are installed in snowbound zones due to very low ambient temperature (Singh et. al. 1997).

The solar water heater, solar cooker, solar lanterns domestic light and improved smokeless stoves (chulha) are also used. More farmers are coming forward for their adoption due to subsidised cost. But these are successfully adopted by medium scale and large categories of farmers only. The improved smokeless chulha is also used by small and marginal farmers and they are saving fuel wood due to its higher efficiency. Few farmers save electrical energy by using old water mills for flour and rice milling.

Post-harvest Technology

The farmers have their own traditional ways of storing and processing farm products for their daily consumption. The post-harvest losses in quality and quantity are very high. The State government helps farmers sell their products at remunerative prices through 35 regulated markets under 10 market committees. About 261,180 vegetables are surplus for marketing but the losses are great due to lack of its processing, packaging and transportation facilities, hence, some promising, high value crops/vegetable/fruits are not being grown on commercial scale.

Mechanization Potential

Farm Power, Tools and Implements

There is need to develop small tools and implements for tillage, sowing, interculture, harvesting and threshing operations which can meet the requirement of 63.83% marginal farmers whose average size of operational land holding is 0.4 ha. The percentage of marginal farmers are higher compared to the country average (**Table 3**). Though some farmers keep tractors and used on custom hiring basis. The tractors are mostly used in plain valleys of this state. There is a tremendous scope for light weight power tillers with efficient matching equipment and machine for field preparation, puddling, sowing, interculture, harvesting, threshing, water lifting, transportation, power take or for indoor activities which can be raised/lowered with the help of two or three men. This mechanical power will suit to only 15.78% of the medium-and large-category farmers, but on custom hiring basis, the percentage may go up to 25%. There is a declining trend in the numbers of bullocks in the state as their maintenance for taking only 30 to 40 days field work in a year is not as beneficial as maintaining a milch cattle. However, it is not possible to fully replace bullock power with mechanical power. To maintain eco-friendly system, there is need to enhance the use of draught animal power by development of suitable and efficient matching equipment. The present level of land productivity can only be increased satisfactorily by adopting efficient farm power and matching equipment.

Land and Water Management

The net area sown in the State is only 11.27% of total geographical area while net area sown in India is 42.63% (**Table 2**.). Hence there is need for additional area which can be brought under cultivation by adopting reclamation measures and converting follow land through deep tillage, levelling, bunding etc. Of course, considering the alarming rate of soil erosion in cultivated lands and maintaining favourable eco-system it is not advisable to convert forest land or well vegetated grass lands into cultivated lands due to various reasons. In the state there exists a scope for converting some non-agricultural land into cropped land. There is need to increase at least 5% more net area sown of geographical area for agriculture purpose. Besides this, there is also need to conduct in depth study for water management as only 19.92% area is under irrigation which is also less than national average (35.75%). This aim can be achieved by the adoption of small irrigation schemes. The amount of water available in the state is many times more than the crop water requirement to cover all the cropped area under irrigation. But topographic situations are such that lifting and conveyance of water to cropped fields are difficult.Practically, it is possible to bring about 80 per cent of cropped area under irrigation in the state through excess rain water harvesting in tank and its recycling, lifting water from perennial streams and conveying it to nearby irrigated patches through pipelines, diverting perennial flows at higher up stream points and conveying it through gravity pipelines to cropped field and collecting small subsurface seepage streams in tanks and using it for irrigation. However, lifting and conveyance are not economically viable in 50% of the cases because of high lift and distant location of cropped area in small patches requiring more pipe length and lift energy per unit of area irrigated. A survey of small watersheds indicate that it is viable (economically as well as practically) to bring 30% of the cropped area under irrigation easily through very small level irrigation projects if operated and managed by the users. Further, it is possible to save water and expand about 10% of the present irrigated area by the use of water losses control measures in water conveyance and by the use of

Fig.1 Farming scene of Himachal Pradesh - showing terrace size and intervals.

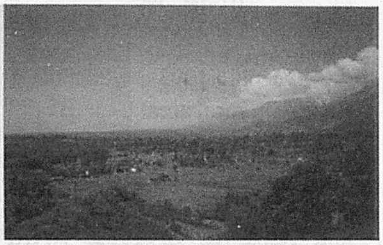

Fig.2 Farming scene of Himachal Pradesh - showing terrace size and intervals.

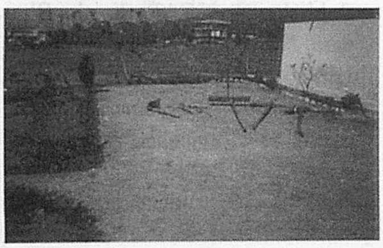

Fig.3 Common tools and equipment used. From left to right: Spade, khunti, kudal (small spade), plane sickle, wooden hammer "Bikkar" (used for breaking clods in the field), animal drawn clod breaker, soil steering plough and indigenous plough.

sprinkler and drip irrigation system wherever possible.

Soil and water engineering works are pre-requisite of adoption of other improved farm inputs in development of rainfed watersheds. Intensive and creative efforts by agricultural engineers, soil scientists and agronomist with inter-disciplinary approach are likely to increase biomass production in rainfed watersheds of the state by 100-150%.

Renewable Energy

The State has vast potential for biogas generation as the state has 2.79 million cattle and buffaloes (**Table 6**). If 60% cattle @ 6 kg dung/cattle can be utilized for this purpose then nearly 0.33 million 2m^3 family size biogas plants can be installed which will be sufficient for more than 1.32 million persons. This will also save more than 1801.1 mt of fuel wood/day and also provide 8,300 mt biogas digested manure per day. Thus, biogas itself will be a milestone for self dependence on energy and saving deforestation. There is also a need for developing appropriate designs of biogas plant which can suit the hilly conditions and further research to minimize low temperature problems.

The mean ambient temperature throughout year in the State is between 8.07 ℃ and 26.2 ℃ and due to low ambient temperature, the energy requirement is great which is met by coal /electricity / fire wood or in combination. The State has about 250 days of sunlight. If 10% of solar radiation (1 kw/m^2 surface) is harnessed in the state at an average efficiency of 15% and availability of 0.01% surface area of geographical area, the potential of energy generated will be 8.35×10^2 MW which will be sufficient to meet the domestic energy requirements of the farmers in the State. The vast and unending source of solar energy can be effectively adopted for heating, cooking, lighting, refrigeration, drying grain and farm crops etc. It is estimated that fuel consumption /person/year is around 0.52 mt in rural areas of H.P. (Joshi, 1993) which is greater than national average (0.24 tonnes).

The other source of energy in the State is water flow. The major rivers and their perennial tributaries can be utilized for domestic energy requirements through water mills and small scale hydroelectric units. At present, water mills are operated by age-old techniques. The effective steps for harnessing renewable energy in the state are required by the agricultural engineers/ scientists/ developmental agencies.

Post-harvest and Agro-processing

The increased agricultural production necessitates improved post harvest processing to increase income of the farmers. It is, estimated that food grain losses in the country is at about 10% in the case of cereals, pulses and oilseeds and up to 40% in the case of fruits and vegetables. Plastic storage structures and vacuum storage of foods, including controlled atmospheric packaging have vast potential. In the state, losses of fruits and vegetables are much more in the absence of fruit and vegetable processing units. Various off-season vegetables are grown in the state but lack of post harvest measures has deprived farmers from getting full benefit. Similarly, the food industry is also the need of the state to enhance the income of the farmers as well as state by adopting soybean and maize crop cultivation in large scale.

Skilled Manpower

The State has a negligible number of agricultural engineers. To meet the above challenges and to harness available potential in the State, there is need to produce adequate agricultural engineers, diploma holders and skilled manpower in the state. At present there is no agricultural engineering college in the State. The State agricultural university needs an agricultural engineering college for specialized training in different agricultural engineering fields to cater to future needs of farm mechanization in hill agriculture of the State. In addition to developing adequate skilled manpower according to future needs, the college can also impart training in farm power, machinery, land development, irrigation, drainage, watershed management, renewable energy and post harvest technology to developmental workers and entrepreneurs.

Conclusion and Suggestions

The agricultural mechanization in the state is in its very early stage and needs immediate attention. Some suggestions for enhancing the pace of mechanization in the State are given below:

1. There is need to produce adequate agricultural engineering graduates, diploma holders and skilled manpower and their placement by the State government.
2. There is need to develop agricultural engineering package for hill agriculture.
3. The developed equipment from other places needs testing, evaluation and modification for their adoption in the lower and upper hills of Shivalik region.
4. Light weight power source (power tiller) is the need of hill agriculture.
5. Follow land and unused land should be brought under cultivation.
6. Creation of small ponds/water harvesting tanks for collecting surface/sub-surface runoff for irrigation purpose.
7. Lifting and conveyance of perennial stream water for irrigation.
8. There is need to develop new models of biogas plants, preferably prefabricated.
9. Some microbial culture is also needed which can grow under psychrophlic conditions.
10. Low cost solar water heater, cooker and dryers are necessary.
11. There is need to upgrade the present technology of water mills.
12. There is need to ensure availability of spare parts and small scale machinery manufacturing facilities.
13. There is need to strengthen the research and development activities in post-harvest and agro-processing area.
14. There is also need to introduce custom hiring system through State goverment agency.

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Selection of Farm Power by Using a Computer Programme

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Bangladesh

Abstract

A computer programme was developed to select the proper power level based on farm size, cropping patterns, cultural practices, crop yield, purchase price of machine and value of crop. The programme was designed in order to minimize the total costs. The basic management data for the selection of farm power were collected from farmers, dealers and different sources. The computations were carried out with a computer programme written in the BASIC. For 200ha land area, the power level for land preparation and farmstead operations in multicrop system was 205 kW and it was 319 kW for rice cultivation in all season (monocrop). The numbers of large tractors, small tractors and power tillers were determined based on the rated power of 50 kW, 30 kW and 9 kW, respectively. It was found that the optimum level of power varied with the size of the farmland and cropping patterns.

Introduction

The selection of appropriate size of farm tractor and equipment is one of the important decision parameters of agricultural mechanization planning and machinery management. There are many factors affecting the selection and use of tractors such as agricultural conditions, farming requirements of soil and crops, management scale and economic conditions (Depeng et al, 1983). As the choice of a particular tractor size depends mainly on soil type and nature of operations to be carried out for various crops, it is reasonable to make such a choice based upon economic performance (Mathews, 1982). On small farms, generally one tractor is expected to do almost all jobs and there is not much flexibility in the choice of a particular size of a tractor. Whereas on large farms, one can select two or more tractors of different types or sizes within the range of minimum power requirements to suit various farm operations. However, there are advantages and disadvantages associated with using tractors of different sizes (Culpin, 1976).

Computer programs are being used to assist farm manager and scientists in decision making about how to manage their machines or production operations and how to select their machinery requirements effectively (Burrows and Siemens, 1974; Hughes and Holtman, 1976; Singh and Holtman, 1979; Rots *et al,* 1983; Hetz and Esmay, 1986; Oskan *et al,* 1989).

In the present study, a computer program for selecting the optimum power level of the tractor, which the farm should own depending on the farm size, cropping pattern and soil and climatic peculiarities of the Mymensingh region, is developed and explained. For this purpose, the required data have been collected and analysed, and a computer program in Quick BASIC language was developed for selecting the optimum power level of the tractor.

Methodology

Power selection is associated with farm size, cropping pattern, cultural practices, crop yield, purchase price of machine and the value of the crop. The farm sizes varied from 5 to 300 ha in finding the required power. Two cropping patterns were assumed. In cropping pattern-1, five crops would be grown in three seasons. Rice (Aus,

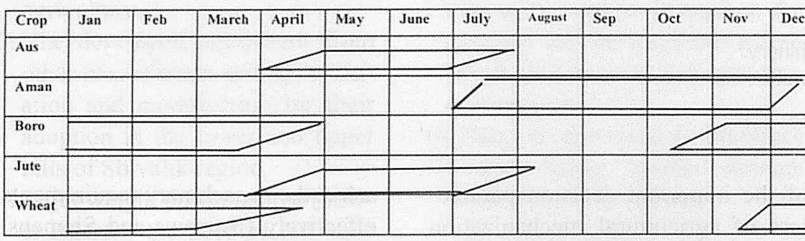
Table 1. Land Area Distribution

Season	Crops to be grown	Land area distribution (% of total area)	
		Cropping pattern-I (multi-crop)	Cropping pattern-II (monocrop: rice only)
Kharif-1	Aus	80	100
	Jute	20	0
Kharif-2	Aman	100	100
Rabi	Boro	60	100
	Wheat	40	0

Table 2. Cultural Operations for Different Crops

Crop	Plowing	Harrowing	Puddling	Transplanting	Weeding	Harvesting	Rating
Aus	0	1	1	1	3	1	0
Aman	0	0	2	1	3	1	0
Boro	0	1	1	1	3	1	0
Jute	0	2	0	0	3	1	2
Wheat	0	2	0	0	3	1	0

Source: Department of Agronomy, Bangladesh Agricultural University, Mymensingh.



Source: Krishi Khamar Byabasthapana by Iqbal, Alam and Gaffar, 1989.

Fig.1 Crop Calendar.

Aman, Boro) was considered as the main crop. Jute and wheat crops were taken for the season of Kharif-1 and Rabi, respectively. The area allocation for Aus and Jute was 80% and 20%, respectively, in Kharif-1. In Kharif-2 only rice (Aman) was assumed to be cultivated. In the Rabi season 60% of the area will be covered by Boro and the rest by wheat. In cropping pattern-2, Aus, Aman and Boro rice would be grown in their respective seasons. The area allocated for Aus, Aman, and Boro was 100% in each season. The land area distribution among the crops and the crop calender are shown in **Table 1** and **Fig. 1**, respectively. The selected cultural operations for various crops are given in the **Table 2**.

The areas allocated for different crops are calculated based on **Table 1** using the following equation:

$$CA_i = A * AP_{ij} / 100 \text{.........} (1)$$

Where,

CA_i = Area allocated for a particular crop i, ha/yr

A = Total cultivated area, ha

AP_{ij} = Percent of total land covered by i crop and j cropping pattern

$_i$ = Different crops, Aus, Aman, Boro, Jute and Wheat

The total area per year for harrowing and rotavator operations are calculated based on **Table 2** using the following equation:

$$TA_j = \sum_{i=1}^{n} CA_i * NOP_j \text{........} (2)$$

Where,

TA_j = Total area covered per year by j operation (Harrow, rotavator etc.), ha/yr

NOP_j = Number of pass required in j operation

The crop yield value of different crops are calculated by using the following equation:

$$YV_i = Y_i * CA_i * V_i \text{.............} (3)$$

Where,

YV_i = crop yield value of i crop, Tk/yr

(In the crop yield value calculation only crop value is considered omitting the value of crop residue)

Y_i = Yield of i crop, ton/ha

V_i = Value of i crop, Tk/ton

The total yield-value of harrowing and rotavator are calculated by using the following equation:

$$YVHR_k = \sum_{i=1}^{n} YV_i \text{.............} (4)$$

Where,

$YVHR_k$ = Yield-value of crops needed k operation, Tk/yr

n = Number of crops needed k operation

k = Harrow or rotavator

The yield of the crop was collected from the Bangladesh Agricultural University farm and the value of crop was taken from the Mymensingh local market (Awal and Roy, 1996). The market prices of tractor, power tiller, disk harrow and rotavator were collected from a dealer "Green land tractors, 1-3 Motijheel C/A, Dhaka" (Awal and Roy, 1996).

The energy requirement in kW-hr/ha (E) is calculated by the following equation;

$$E = \{\text{Rated Power, (kW)}\} / \{\text{Effective field capacity (ha/hr)}\} \text{...} (5)$$

The field capacity and rated power were collected from the report of Hossain and Alam, (1995).

In determining the fixed cost, the depreciation is calculated by the straight line method considering 10 years life and 10% salvage value. Interest rate was assumed to be 8%. Thus, total fixed costs per year was considered as 16% of the purchase price.

The annual cost (AC) for tractor power is expressed as the sum of the fixed costs (Fc) and the total labor (L) and timeliness costs for each of the three types of farm jobs; field work, transport work, and processing work, (Hunt, 1979), hence the following equation:

$$AC = (Fc\%)*P/100 + \text{hr field work (L+timeliness)} + \text{hr transport work (L)} + \text{hr processing work (L)} \text{.................} (6)$$

Based on this equation, the optimum power level (pwr) was determined on the basis of minimum cost **equation** (7).

Where,
W =Transport load, ton
D =Distance travelled, km
C =Constant, 2.7
G =Factor for several processing operations on farm, kW-hr/ton
ri =Typical ratio of tractor output power to PTOP, decimal
i =Subscript identifying specific operation, areas, energy, values, labor costs etc.
n = Number of operation
Σ = Sum evaluated for all i operations
t = Cost for unit power, Tk/kW
K =Timeliness loss factor, l/day
Sc=2 for premature or delayed schedules, 4 for balanced
nt = Number of times.
U =Fractional utilization of total time, decimal
h = Daily work, hrs/day

Several constants such as Sc, nt, U, G, r and K were used in the above equation were taken from Hunt, 1979. Three sizes of tractors were selected based on power e.g., large tractor (50 kW), small tractor (30 kW) and two-wheel tractor or power tiller (9 KW). The small tractor and power tiller were selected for the farm size less than 100 ha. However, only the large and small tractors were considered for the farm size of 100 ha or more. The equation was solved by a computer program the flow chart of which is shown in **Fig. 2**.

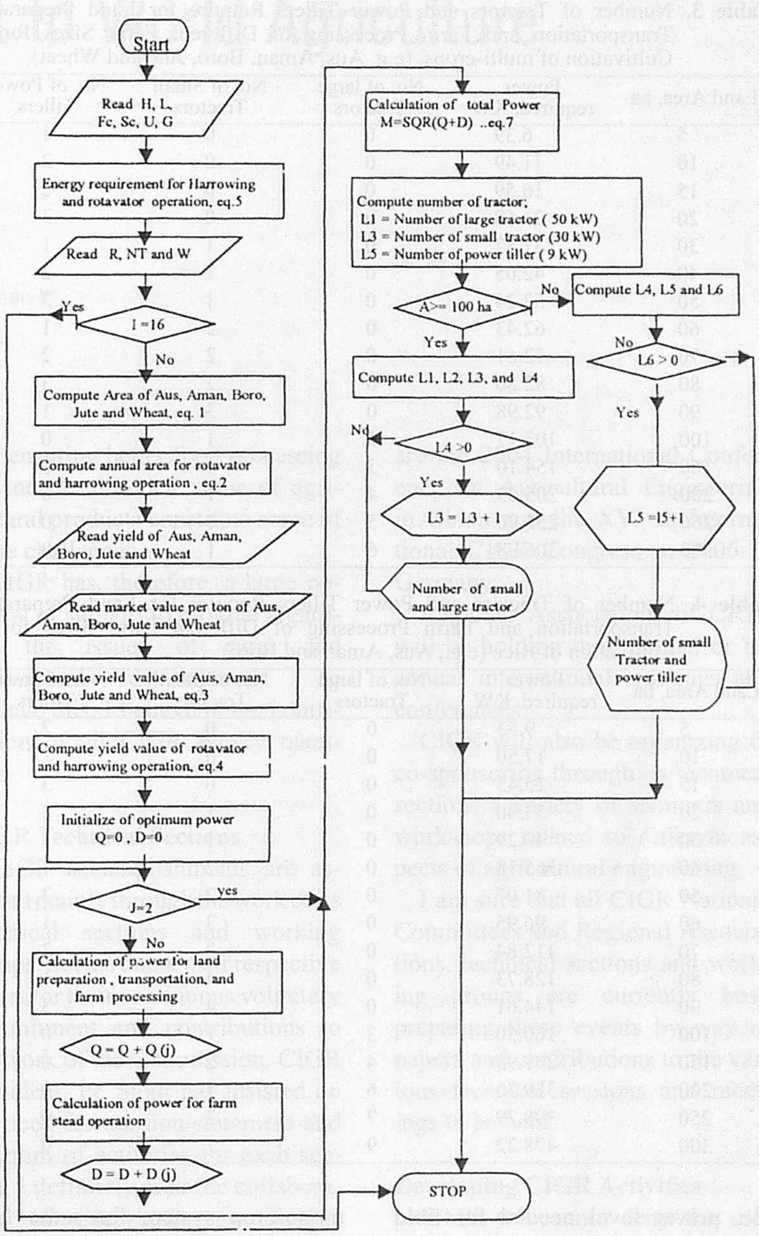


Fig.2 Flow chart of the program.

Results and Discussion

The power requirements for land preparation, transportation and farm processing for different farm sizes and cropping pattern were determined. Farm sizes varied from 5 ha to 300 ha. Small tractors and power tillers were used up to the farm size of 100 ha. Large tractors and small tractors were used for farm sizes above 100 ha. This was done to reduce the number of power units and minimize the cost of maintenance, labour and shelter.

$$pwr = \sqrt{\left[\sum_{i=1}^{n} \left\{ \frac{100 * E_i * CA_i}{r_i(FC\%)t} \left(L_i + \frac{K_i * YV_i}{(Sc)_i * (nt)_i * H_i * U_i} \right) + 100 \frac{L_i}{(FC\%)t} \left(\frac{CD_i \cdot W_i}{r_i} + \frac{G_i * W_i}{r_i} \right) \right\} \right]}$$

Equation (7)

Table 3 represents the number of tractors and power tillers required for the cultivation of multicrops (Rice: Aus, Aman, and Boro, Jute and Wheat) in a year. **Table 4** shows the same for mono-crop (Rice: Aus, Aman, and Boro) cultivation.

From **Tables 3** and **4**, it is observed that in monocrop (only rice in all seasons) system power or energy requirement is greater than that in multicrop system. For exam-

Table 3. Number of Tractors and Power Tillers Require for Land Preparation, Transportation and Farm Processing of Different Farm Sizes for the Cultivation of multi-crops. (e.g. Aus, Aman, Boro, Jute and Wheat)

Land Area, ha	Power required, KW	No. of large Tractors	No. of Small Tractors	No. of Power Tillers
5	6.39	0	0	1
10	11.49	0	0	2
15	16.59	0	0	2
20	21.68	0	0	3
30	31.87	0	1	1
40	42.05	0	1	2
50	52.24	0	1	3
60	62.43	0	2	1
70	72.61	0	2	2
80	82.80	0	2	3
90	92.98	0	3	1
100	103.17	2	1	0
150	154.10	3	1	0
200	205.03	4	1	0
250	255.96	5	1	0
300	306.98	6	1	0

Table 4. Number of Tractors and Power Tillers Require for Land Preparation, Transportation and Farm Processing of Different Farm Sizes for the Cultivation of Rice (e.g., Aus, Aman and Boro)

Land Area, ha	Power required, KW	No. of large Tractors	No. of Small Tractors	No. of Power Tillers
5	9.53	0	0	2
10	17.50	0	0	2
15	25.45	0	0	3
20	33.40	0	1	1
30	49.29	0	1	3
40	65.18	0	2	1
50	81.07	0	2	3
60	96.95	0	3	1
70	112.84	0	3	3
80	128.73	0	4	1
90	144.61	0	4	3
100	160.50	3	1	0
150	239.93	4	2	0
200	319.36	6	1	0
250	398.79	7	2	0
300	478.22	9	1	0

ple, power level needed for field operations and farmstead operations in only rice cultivation in 200 ha land area is 319 kW whereas in multicrop system this is 205 kW. In rice cultivation, area coverage by rotavator operation was greater than that in the multicrop system in three seasons (shown in **Table 1**). Besides, energy requirement for rotavator operation was comparatively high. For this reason, monocrop system showed greater power requirement than multicrop system.

In multi-crops system up to 20 ha only, 3 power tillers are sufficient for farm operation but in mono-crop system for same farm size one small tractor and one power tiller are needed. A 50-ha farm size for multi-crop cultivation with land distribution based on **Table 1** requires 1 small tractor and 3 power tillers whereas the mono-crop system needs one more small tractor, (**Tables 3 and 4**).

In this study it was assumed that most of the farm operations were carried out either by tractor or power tiller. Farming operations by hand tools and animal-driven implements were not included in the study. The values of several constants such as Sc, nt, U, G, r and K were used from Hunt (1979) in equations since these values are not available for Bangladesh condition. Whenever the value of these constants will be determined for Bangladesh condition, farm power requirement can be calculated more accurately using the present developed program.

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CIGR Commitment to World Agriculture

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Honorable delegates, ladies and gentlemen, dear friends:

I am pleased and honored to address this General Assembly a few weeks before my term of CIGR Presidency starts and while we are celebrating the XIV memorial CIGR Congress in Japan.

Great efforts have been made to develop CIGR activities during the last years, while at the same time streamlining its administrative and working arrangements at the successive locations of its General Secretariat.

I would like to thank all past Presidents of CIGR for the excellent work and contributions they have made during their respective terms, namely; those who have shaped CIGR into the Global Organization that it is: Pr. Pellizi, Pr, Berge, Pr. Kitani and Pr. Stout as well as our former General Secretary: Dr. Daellemans and present General Secretary: Dr. Schulze Lammers.

Challenges Ahead

CIGR needs to address the ever important and vital global issue of food security for people.

I am aware of the numerous challenges ahead of us. World agriculture is facing a variety of difficulties mainly in developing countries. Fighting drought, flooding, salinity, and desertification, ensuring environment protection, biodiversity and adequate energy input, reducing post harvest loss and ensuring better food processing for increased added value of agricultural products constitute some of these challenges

CIGR has, therefore, a large potential of support to provide regarding the issues of rural and agricultural development. To achieve this, I believe in the contribution of all CIGR family members.

CIGR Technical Sections

CIGR accomplishments are assessed mainly through the work of its technical sections and working groups. Let me thank their respective chairs for their continuous voluntary commitment and contributions to the work of the Commission. CIGR President, Pr. Stout has insisted on the need for mission statement and program of activities for each section. I definitely seek the collaboration of everybody for further improvements in the future.

CIGR has just added a new technical section to its structure. In this way, it will be able to adequately cover the important topic of information systems and use this potential to improve production and processing of agricultural products.

Scheduled Activities

The two coming years are another milestone period for CIGR with the joint XVth International CIGR and ASAE congress to be held in July 2002, in Chicago, in the US.

Other important meetings ahead are the 2004 International Conference on Agricultural Engineering in China and the XVI th International CIGR Congress in 2006 in Germany.

Regional Associations of CIGR will be holding their annual or biannual international meetings and conferences.

CIGR will also be organizing or co-sponsoring through its technical sections a variety of seminars and workshops related to different aspects of agricultural engineering.

I am sure that all CIGR National Committees and Regional Associations, technical sections and working groups are currently busy preparing these events by way of papers and contributions to the various technical sessions and meetings to be held.

Developing CIGR Activities

While we cannot deny the success CIGR has achieved globally, gaps continue to remain between developed and developing countries. There is a great potential to bridge these gaps for mutual and common benefit. It is here that CIGR, with its current more representative and streamlined organization structure, is well placed to take further positive steps. Such steps will promote greater international co-operation to meet the challenges ahead as we move unto the 21st century.

The Joint CIGR-FAO on Line Group discussion further strengthens our existing ties with FAO with prospects for greater collaboration in the future.

Efforts are constantly made to improve the web of CIGR, I would like to recommend that you visit it more frequently in the future at www.ucd.ie/cigr/.

The Electronic Journal of CIGR is a peer-reviewed journal of scientific research and development. Its address is www.agen.tamu.edu/cigr/. This initiative introduced by CIGR in 1999 is to be developed. CIGR welcomes contributions from individuals and national associations.

The CIGR Newsletter and Bulletin printed in English and French are released for the purpose of sharing and dissemination of information and experiences of common interest. I would like to urge CIGR members to fully avail of this opportunity to contribute news or views.

The CIGR Handbook is a valuable tool for training and research institutions, particularly in developing countries. CIGR is grateful to all the persons and organizations who offered copies of this handbook to libraries in developing countries. A second edition is under consideration. CIGR is taking into account the need to orient it to professional and extension users.

CIGR is aiming at better disseminating its activities into a larger area of the world and **attract new national or regional associations.** Six national associations have joined CIGR during the last two years. These are: Australia, Bangladesh, Canada, Czech Republic, Iran, Korea, Mexico, Philippines and Turkey. There is also a new regional association: the Eur-Asian Regional Association of Agricultural Engineering. CIGR welcomes these new members and will value their input.

We still need particularly to encourage French speaking Africa and Arab countries to join, CIGR will examine the possibility of translating

i) the CIGR handbook to French;
ii) the news letter of CIGR to Arabic; and
iii) CIGR leaflets into these two languages.

For this, it will seek support from the French national committee of CIGR, the Francophone University Agency and sponsorship from Arab Organization for Agricultural Development.

An Outlook to Future Directions

Providing food security to all people through increased food productivity will, therefore, be a major task of the world community in the next 20 years and beyond. There is a pressing need to provide enough food for an additional population of 3 billion people by 2050.

The principal tasks will be: to bridge the existing gap between yield potential and the actual yields achieved. Also, priority will need to be given to the development and application of technologies for less favorable ecosystems and crops. It will be imperative to maintain agricultural sustainability and to adopt measures to make existing technologies more acceptable to farmers.

CIGR will remain sensitive to these issues and will strive to address them proactively just as in the past. With limited resources, it must necessarily adopt a focused approach and develop strategic partnerships. This is demonstrated throughout recent efforts in pursuing CIGR electronic publications, new edition of the Handbook on line group discussion, new technical section on information technology and working groups. CIGR will also have to strengthen its international collaboration and develop the involvement of industrial and entrepreneurial sectors in its tasks. The activities of the technical sections and their working groups and their quality outputs must remain our strength in harnessing science and technology to optimum levels in order to achieve our goals.

CIGR has, therefore, many targets to fulfill its mission of service to its members. I will be grateful to all active members of the Commission to continue the excellent work and unstinting help that they give us. It is only through these efforts that we can continue to improve the effectiveness of our activities.

I look forward to a very productive work with our General Secretary Dr. Schulze Lammers and his staff in Bonn and with the Presidium members: Pr. Stout and Pr. Munack. I will also be grateful to Pr. Kitani for his continuous advice after his term of Past President. I renew our sincere gratitude to the German Ministry of Agriculture for all the kind help it keeps providing the General Secretariat of CIGR in Bonn.

Let us work together in pursuing our global mission and look forward to another successful joint CIGR – ASAE Congress in the US in 2002.

Thank you for your attention.

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The Present State of Farm Machinery Industry

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Outlook of Agriculture

Trend of Agriculture

In 1997 agricultural total products was ¥6,400 billion, it occupied 1.2% of GNP. The imports agricultural products are on the increase. In 1998 the imports reached $34.0 billion (a decrease of 8.2% of the preceding year). The exports agricultural products are $1.6 billion (a decrease of 3.6% of the preceding year). In Japan, feed cereals, soybean, wheat and so on depend on the imports from foreign countries. Self-sufficiency ratio of agricultural product for food by calorie base in 1998 is 40%, cereals is 27%.

Population mainly engaged in farming has been decreasing yet, in 1998 it was 3,080,000 persons. It was 4.7% of total working population. Farm house has decreased, in 1998 are 3,290,000 farm houses. And, commercial household was 77%. Arable land was 4,905,000 ha in 1998. Arable land per one farm family was about 1.5 ha very small.

In Japan, food life has varied since 1970's. While, rice, oranges, milk, eggs and so on have been overproduced. In such surroundings, the GATT settlement require Japan to have more competitive power. In Japanese agriculture, it is requested to reduce production cost, increase people destined to bear agricultural production, produce various products satisfying consumers' need, and to realize agriculture keeping the earth favorable.

In July 1999, Japanese government enacted the New Agricultural Stable Law, which aims to assure constant food supply by raising domestic production, to encourage multi-functions of agriculture, to have sustainable development of agriculture and to promote the development of rural areas. The law makes it a target that 50% of national food consumption is covered by domestic production, at least to raise self-supply rate up to 45% by 2010.

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. At present rice production is almost mechanized from planting to harvesting. In 1999, working hours on 10a paddy field reduced to 35.1 hours from 117.8 hours in 1970.

In recent years farm machinery for rice crop is developed to be larger-sized, higher-efficiency and more commonly used. In addition, farm machinery for field crops and live stock farming is being developed and improved, which had been lagged behind so far.

From 1993 Japanese government started the program developing the new high-tech machine to make farm working efficient and to reduce farm burden. By 1998, 24 kinds of new type machines including big-size multipurpose combine and full automatic vegetable planter had been developed. Also to promote mechanization of vegetable cropping, standardization of vegetable cropping method was introduced for 11 kinds of vegetables. Moreover, in 1998 new program developing 28 types machine have started. Local governments have been developing the machine to vitalize special local products.

In 1995 Ministry of Agriculture, Forestry and Fisheries made a committee which studied method to reduce cost of farm product materials like farm machines. Those farm product materials are major parts of farming cost. In 1996 concrete movement started in the field of production and distribution. Low cost machinery with limited functions has been increasing.

Following are the numbers of farm machines in possession of farms as of Feb.1,1995: riding tractor reached 2,309,000 units; walking

Table 1. Major Farm Machinery on Farm — Unit: Thousand

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Power duster	Binder	Combine	Rice dryer
1990	2,185	2,142	1,983	1,871		1,298	1,215	1,282
1991	1,765	1,966	1,904	—	—	—	1,169	—
1992	1,786	2,003	1,881	—	—	—	1,158	—
1993	1,743	2,041	1,866	—	—	—	1,158	—
1994	1,669	2,060	1,835	—	—	—	1,149	—
1995	1,718	2,313	1,869	1,921		1,022	1,203	1,121

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry & Fisheries" by the Ministry of Agriculture, Forestry & Fisheries and Other datas.

Table 2. Shipment Major Farm Machinery Unit: Number

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Power duster	Binder	Combine	Rice dryer
1990	205,944	95,691	89,139	183,820	107,227	37,117	65,247	51,954
1992	199,141	88,754	80,105	184,016	105,028	20,888	60,941	52,275
1994	172,471	88,501	82,210	162,422	98,266	22,589	60,741	57,070
1995	163,323	90,623	81,729	162,352	96,499	23,293	64,572	60,564
1996	173,894	93,660	73,204	165,467	99,342	18,476	60,198	59,546
1997	174,004	87,416	64,859	177,064	90,133	16,770	53,095	52,389
1998	173,397	71,840	52,337	159,215	59,946	11,757	41,282	38,842
1999	180,511	72,533	59,529	166,380	54,717	12,010	40,822	39,416

Source: "Survey of Shipment Agricultural Machinery" by the Ministry of Agr., Forestry & Fisheries.

tractor 1,714,000; rice transplanter 1,865,000; head feed combine 1,202,000 (**Table 1**).

Shipments of major farm machinery in the domestic market in 1999 are as follows: riding tractor reached 73,000 units (those under 20PS were 20,000; those 20-30PS 34,000; 30-50PS 13,000; over 50PS were 5,000); walking tractor 181,000; rice transplanter 60,000; combine 41,000 (standard types were 639); grain dryer 39,000; huller 30,000. The shipment of safety cabins and safety frames attached to tractors rose sharply to 71,000 units (**Table 2**).

Recently more and more used farm machines are distributed. The rate of used farm machinery in 1998 in the total sales amount is as follows: riding tractors 39%; rice transplanter 32%; combine 39%.

Movement of Farm Machinery Industry

Japanese agriculture was rice itself. Rice is stable food of Japanese people. Japanese agricultural history was increasing rice production. Japanese could not eat enough rice recently by low productivity, Japan was eager to have affluent rice. So purpose of mechanization of agriculture was to increase rice production.

This objective was fully attained and set-aside policy has been taken since 1970. Rice has been over production till 2000. Especially, in 2000, rice price fell down by rice over production. This is accelerating the change in Japanese agriculture.

In Japan, most agricultural machineries were for rice production. Also agricultural manufacturers produced machines for rice production. A lot of rice farmers purchased machineries. But most of these farmers are over 70 years old now. They will retire soon. The most significant problem of Japanese agriculture is, who will produce rice.

We have two types, one is large farmers who gathering paddy field, the other is small farmers who are called part-time farmers. They usually have the primary job and work on their farms only on Sundays and holidays. Japanese agriculture, especially rice, will be divided to two types, large and small farmers. In order to cope with this change, agricultural machineries will divide to two types.

What is most important role of agriculture? At first, producing food which is essential to the living of human beings. Recently, agriculture takes an important role in preserving natural resource and improving air and water. Agricultural machineries were tools for production. From now on a role of preserving environment will be added. We will must develop machineries in consideration of preserving environment.

Trend of Farm Machinery Production

Farm machine production in 1999 amounted to ¥540 billion (9.8% increase over the preceding year). It has recovered slightly from 1998.

Production of the major farm machinery is as follows: Riding tractor 156,452 units increased by 8.1% over the preceding year. Seeing by h.p., those under 20PS amounted to 53,533 units, 20-30PS 49,991 units, over 30PS 52,928 units. Over 30PS class showed an increase of 20% over the previous year.

The production of walking tractor amounted to 253,817 units, which showed an increase of 19.4% over the preceding year. Under 5PS was 151,060 units, over 5PS was 102,757 units.

The production of combine, which is next to the riding tractor is 42,173 units (an increase of 4.9% over the preceding year). The most popular type is with harvesting width of one meter head feed.

Following are the production of other types of farm machinery: rice transplanter amounted to 58,137 units (an increase of 9.4% over the preceding year), binder (walking type harvesting machine for rice and wheat, barley, etc.) 11,816 units (an increase of 36.9%), thresher 5,508 units (an increase of 8.0%), grain dryer 36,920 units (an increase of 12.0%), huller 37,579 units (an increase of 33.7%), bush cleaner 1,084,889 units (an increase of 7.2%), power pest-controller 238,005 units (an decrease of 5.4%) so on. (**Table 3**).

Trend of Farm Machinery Market

In Japan distribution systems for farm machinery is roughly divided into two major channels: the dealers concerned and Agricultural Cooperatives Association. As of June 1997, the retail shops were recorded to about 8,800, the employees amounted to 45,000 persons, and the annual sales amounted to

Table 3. Yearly Production of Farm Machinery Unit: Number, Million Yen

Year	Farm machinery total		Riding type tractor		Walking type tractor		Rice trans planter		Power sprayer		Power duster		Blower sprayer	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1990	—	585,561	115,939	198,557	269,027	38,248	91,141	52,462	220,528	12,339	149,789	5,575	9,565	9,514
1991	—	615,131	148,437	203,260	270,714	40,102	87,019	54,265	198,887	10,607	163,306	6,155	9,318	12,766
1992	—	575,986	145,948	195,189	245,675	35,917	80,540	50,760	181,475	7,826	162,040	6,548	9,923	14,884
1993	—	588,627	146,115	186,983	225,564	33,738	84,980	58,344	165,909	6,899	134,901	5,985	8,559	12,155
1994	—	606,279	156,039	198,278	212,539	30,921	85,837	66,726	141,556	6,569	123,268	5,670	6,260	8,261
1995	—	649,874	153,890	205,489	205,758	28,271	86,713	69,218	161,360	7,370	129,995	6,293	7,018	11,622
1996	—	637,209	152,956	201,357	214,702	31,400	70,614	57,581	154,260	6,752	126,594	6,121	8,280	12,843
1997	—	615,974	160,518	219,446	225,229	31,803	63,367	53,236	172,034	7,776	110,736	5,278	7,799	10,223
1998	—	491,973	144,774	194,954	212,551	29,669	53,122	46,218	156,890	7,256	86,535	4,086	7,973	9,204
1999	—	539,960	156,452	220,047	253,817	36,365	58,137	43,146	153,118	7,416	77,693	3,567	7,194	9,282
(2000)	—	535,500	163,000	226,700	249,300	34,600	56,300	45,500	157,500	7,700	92,900	4,200	5,900	9,800

Year	Grain reaper		Brush cutter		Power thresher		Grain combine		Rice husker		Dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1990	42,502	11,110	1,601,652	25,798	22,634	9,118	68,993	138,396	60,006	18,332	59,269	39,990	58,500	4,871
1991	37,782	9,542	1,657,897	27,117	20,337	7,898	72,913	152,827	60,690	19,124	57,747	43,250	57,625	5,243
1992	30,511	7,753	1,890,427	28,994	12,656	4,838	65,673	143,335	50,208	15,292	51,821	38,236	45,182	4,274
1993	27,286	7,173	1,588,837	27,339	11,663	4,562	65,192	149,867	41,664	14,129	56,079	44,224	40,368	3,844
1994	21,033	5,379	1,554,478	28,726	11,422	4,439	61,242	148,537	42,115	14,680	62,044	49,846	53,514	5,493
1995	27,562	7,484	1,471,192	27,731	12,422	4,751	66,767	162,329	56,792	21,178	67,700	56,215	56,590	6,755
1996	21,541	6,364	1,220,005	24,291	11,593	4,568	63,371	168,391	60,021	22,639	64,969	53,483	44,451	6,096
1997	15,027	4,283	948,178	21,071	9,042	3,542	56,709	152,627	56,887	21,434	56,647	46,529	42,391	5,148
1998	8,631	2,336	1,012,372	22,236	5,102	1,988	40,196	103,435	28,113	10,705	32,968	26,543	39,729	3,588
1999	11,816	3,436	1,084,889	24,172	5,508	2,228	42,173	112,145	37,579	14,491	36,920	29,976	36,342	2,464
(2000)	11,600	3,200	1,042,100	24,200	5,600	2,100	41,700	108,600	38,400	14,600	40,100	35,200	39,500	2,900

Source: "Survey of Status of Machinery, Production" by the Ministry of International Trade and Industry. Data by Japan Agr. Machinery Manufactures' Assn. and Land Internal Combustion Engine Manufacturer's Assn.

Note: Data for 2000 are forecast by Farm Machinery Industrial Research Corp.

Table 4. Farm Equipment Distributor and Sales Value
Unit:Million yen

Year	Number of retailers (1)	Employes	Annual sales value (2)	Inventory	Square meters of shop m^2	Annual sales value (2)/(1)
1979.6	9,257	48,548	1,007,298	159,772	898,854	108.8
1982.6	10,084	49,081	1,018,983	164,269	1,005,546	101.0
1985.6	9,142	43,921	946,507	144,837	985,453	103.5
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5
1991.6	9,480	45,705	1,158,924	170,104	984,700	122.2
1994.6	8,838	43,112	1,128,087	166,298	978,788	127.6
1997.6	8,820	45,090	1,265,902	170,350	901,851	143.5

Source: Ministry of International Trade and Industry.

Table 5. Handling of Farm Equipment by Agricultural Cooperative Association (1998 Business Year)
Unit: Million yen

Business year	Total number of coops. surveyed	Purchase in this term	Of which purchased through affiliated organs	Amount of supply and handling
1990	3,591	349,521	268,763	375,660
1992	3,204	354,728	268,393	388,031
1994	2,669	378,660	281,625	417,474
1995	2,457	374,952	283,193	413,664
1996	2,331	374,334	279,070	415,691
1997	2,112	310,008	229,205	342,423
1998	1,840	274,510	200,124	313,107

Source: "Statistics on Agricultural Cooperatives—1995 business.

¥1,265.9 billion (**Table 4**).

According to the governmental survey by Ministry of Agriculture, Forestry and Fisheries, the total sales of farm machinery by Agricultural Cooperative Association reached ¥313.1 billion in 1998 (¥342.4 billion in 1997) (**Table 5**). In 1998 the number of Agricultural Cooperative was about 1,840. Amount of dealing machines per Cooperatives was about ¥190 million.

About half of dealers are small firms which employ less than 5. In a long time view, it is an important problem to improve management structure.

Export and Import of Farm Machinery

Export

In 1999 the export of farm machinery amounted to ¥149.1 billion, which showed an increase of 3.6% over the preceding year. The ratio of exports to the total production amounts to ¥540.0 billion ended 27.6%.

Seeing by the destination, ¥77.6 billion for North America (an increase of 3.1%), ¥23.4 billion for Asia (an increase of 2.0%), ¥33.5 billion for Europe (an increase of 3.6%). For North America, ¥72.7 billion was for U.S.A., tractor 69,222 units, ¥60.3 billion, which was a major part (**Table 6**).

As for the types of farm machinery, tractor was chiefly exported: 117,708 units were exported in 1999 (the total production was 253,817 units). It amounted to ¥86.5 billion. Seeing by horse power, those under 30PS amounted to 81,540 units, those from 30 to 50PS 28,897 units, those over 50PS 7,271 units.

Major farm machinery, next to tractor, is bush cleaner. The total exports were 1,204,233 units, ¥26.3 billion. The exports of other farm machinery are as follows: walking tractor 75,670 units; power sprayer

Table 6. Export of Farm Equipment 1999

Unit: FOB million yen

Year	Unit	Value	Ratio	Major destinations
1990		132,757		
1991		129,943		
1992		143,891		
1993		124,505		
1994		120,079		
1995		104,597		
1996		113,586		
1997		130,351		
1998		143,843		
1998		149,066		
1999		149,066	100.0	U.S.A., Taiwan, France
Power tiller	75,670	4,668	3.1	France, Sri Lanka, Vietnam
Wheel tractor	117,708	86,550	58.1	U.S.A
Seeder, Planter	1,327	1,224	0.8	Taiwan
Power sprayer	50,731	1,611	1.1	Korea,Mexico, Taiwan
Duster	19,860	506	0.3	U.S.A, Korea,
Lawn mower	39,307	4,619	3.1	France,U.S.A., Belgium
Brush cutter	1,204,233	26,347	17.7	France, U.S.A., Italy
Mower	13,935	377	0.3	Malaysia,Korea
Combine	2,323	5,909	4.0	China., Taiwan
Chain saw	180,924	3,776	2.5	U.S.A., Italy, France
Other	—	13,273	9.0	

Source: "Ministry of Finance. Totaled by Japan Farm Machinery Manufacturer's Assn.

Table 7. Import of Farm Equipment 1999

Unit: CIF million yen

Year	Unit	Value	Ratio	Exporters
1990		33,205		
1991		26,598		
1992		25,778		
1993		25,578		
1994		27,779		
1995		27,015		
1996		33,542		
1997		33,069		
1998		27,513		
1999		23,308	100.0	Germany, U.S.A., U.K.
Wheel tractor	2,026	7,405	31.8	U.K., Germany, France
Pest control machine	2,865,360	1,522	6.5	China, U.S.A., Taiwan
Lawn mower	38,697	1,796	7.7	U.S.A., Sweden, Germany
Mower	2,197	687	2.9	France, Netherlands, Germany
Hay making machine	875	661	2.8	France, Denmark, Netherlands
Bayler	520	883	3.8	France, Germany U.S.A
Combine	64	949	4.1	Belgium, Germany,
Chain saw	59,982	1,509	6.5	Germany, Sweden, U.S.A.
Other		7,896	33.9	

Source: "Ministry of Finance. Totaled by Japan Farm Machinery Manufacturer's Assn.

50,731 units; lawn mower 39,307 units; grass mower 18,120 units; chain saw 180,924 units, etc.

Import

In 1999 the imports of farm machinery amounted to ¥23.3 billion, which means a decrease of 15.3% under the preceding year.

Followings are the major imported farm machinery: tractors 2,026 units (those more than 70PS were 1,562 units of all the tractors); chain saw 59,982 units, lawn mower 38,697 units, mower 4,513 units, fertilizer distributor 986 units. Tractors 774 units were imported from U.K. and 337 units from German. **(Table 7)**.

Trend of Research and Experiment

The surroundings of Japanese agriculture are very hard, because of claims for opening the market for agricultural products by U.R. Settlement, consumer's various favor, the decrease of the new farmers, being called for the contribution to solve the environmental problems. That's why the structural and technical reforms in Japanese agriculture are required urgently.

The research effort was chiefly made for high performance, automatic and popularized farm machinery in order to reduce burden of farm working. Electronics and mechatronics have been positively adopted for their technology. In 1993, the law to promote agriculture mechanization was revised. In 1993 "Urgent Development Program" started for the objective of developing the machine critically needed by some farmers, but with low market demand. As a result, new machine like vegetables grafting machine came to market. And in 1998, new "Urgent Development Program" including 27 types study started.

In 1999, in the field of farm machinery of public research institutes, there were movement as follows;

In the field of tractor, development of auto-running systems, multifunction tractors and implement for slope grass field was made.

In rice production, direct sowing methods are vigorous. Studies have been developing, and which are high dense type and auto-running type rice planter machines. Also it have been studying that auto-running robot for taking off weeds in the paddy field.

In vegetable production, many planters and harvesting machines has been developing. There have been trial producing of chemical sprayer which work spot spraying and weeding machines for field.

In fruits production, study of fruit-tree planters and machines working in slope, fertilizer distributor, pest control machine have been developing. Multipurpose monorail are developing.

In stock rising, it has been developing that technology for easy refresh grass with seed-cube, shallow slurry injector, taking off dusts and smell in animal house, stack-silo machines, small cutting roll-baler and forage mat maker.

In the field of human engineering and safety, evaluation system for comfortableness of agricultural works and safety information system for farming machineries, and so on have been developed. ■■

The IAM-Brain and Important Notes

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Introduction

From the beginning of 1950s, the mechanization of Japanese agriculture was really going into action. The development of mechanization has contributed to labor saving, the improvement of agricultural productivity and the increase of income of farm workers. Now, it is absolutely necessary for agricultural production to use agricultural machinery.

In recent years, the Japanese society faced various problems caused in changes in nations' value system. The Japanese government is wrestling with improving its systems to a secure safe and comfortable life for the general public in the twenty-first century.

The conditions in Japan are equally changing greatly in terms of food habits, agriculture, and rural areas, following changes in the economy and the development of internationalization. The country's agricultural and rural areas play important roles in environmental preservation and the both traditional and regional cultures, as well as in eating habits.

The Japanese Diet established new basic laws regarding food, agriculture, and rural areas in 1999. The new laws are important public issues in the coming new age to review the existing 40 year old Agricultural Basic Law. This New Agricultural Basic Law is composed of four fundamental ideas: ① securing a stable food supply; ② fulfillment of the multifunctional roles of agriculture; ③ sustainable agricultural development; and ④ the development of rural areas. This law is the fundamental guideline for food, agriculture, and rural areas policies. The Japanese government is now working to put this plan into effect.

Under these circumstances, the Bio-oriented Technology Research Advancement Institution (BRAIN), which is a governmental corporation, is playing an important role in the domain of research and testing of agricultural machineries in Japan. Here, we introduce the Institute of Agricultural Machinery (IAM), Brain and its activities on research and testing.

Establishment and History

The IAM was founded in 1962 as an offshoot of the Agricultural Mechanization Promotion Law. The IAM is a governmental corporation with joint financing from the government and private sector with the purpose of promoting agricultural mechanization through research, development and testing of agricultural machineries.

In the beginning, the main office was located at Konosu city in Saitama prefecture, but moved in 1964 to its present location in Omiya city, also in Saitama prefecture. The organization at the time consisted of the survey and information division, the general affairs department, 1st research department, 2nd research department and the testing department. Later, the IAM enlarged the research department and strengthened the testing department. It also acquired an experimental farm and a planning department.

Between its founding in 1962 and 1969 research work at IAM was focused on the development of machinery for rice farming, particularly by developing rice transplanters and harvesters.

Since 1970, the research emphasis has expanded to the mechanization of the livestock industries, horticulture and upland farming by enlarging the organization and activities of the research departments. Since 1976, research on durability and safety of agricultural machinery has been intensified. Furthermore, since 1978, IAM has worked to develop urgently needed machinery to be used for upland fields which have been converted from paddy fields according to the government's plan to reorganize paddy field utilization, and to develop energy-saving machinery. With regards to the research fruits, IAM developed new machinery such as up-cut rotary tiller, low volume sprayer, soybean reaper, spiral-flow thresher for soybean, cabbage harvester, rice husk gasification system.

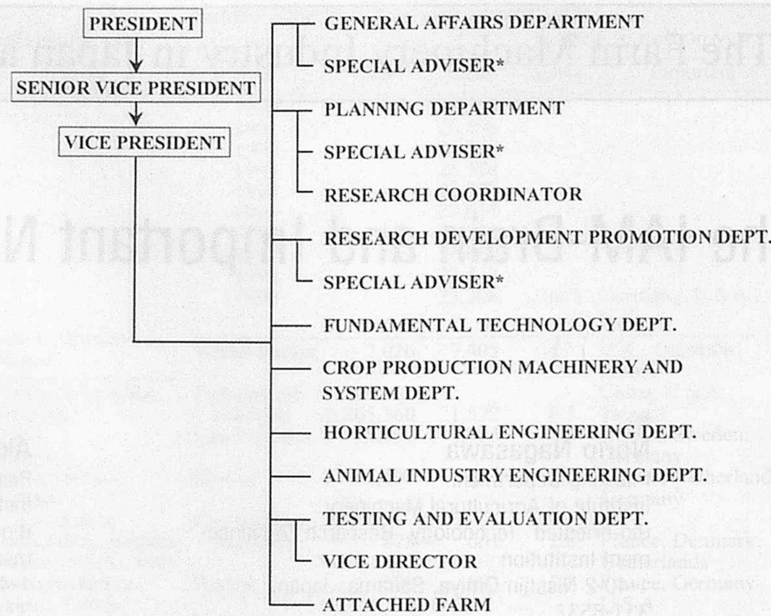
In addition, IAM developed a combine for multi-crops and high performance rice transplanter in 1984 and 1985. The newly developed threshing and planting machineries have become a major interest in the reduction of production costs.

As for testing activities, the IAM has been designated to carry out national tests based on the Agricultural Mechanization Promotion Law. In 1966, IAM including the testing station for "the test by OECD standard test code for agricultural tractors". Furthermore, the Safety Tests for agricultural machines was initiated in 1976 to ensure the safety of farm workers.

Enter the BRAIN

The BRAIN was founded in October 1986 as a legally approved corporation, inheriting the entire properties and activities of the previous governmental corporation, IAM, which spearheaded researches and tests for the promotion of agricultural mechanization in Japan. The new Institution meets the national needs to stimulate and promote biotechnological in private enterprises, through investment and loans by the BRAIN.

The agricultural mechanization



* Located in Tokyo office

Fig. 1 Organizationnal flow chart of IAM.

promotion departments of the BRAIN did not entirely abolish the IAM even after the establishment of the BRAIN. In fact, the IAM still assumes the principal role in the domain of researches and tests on agricultural machinery.

In October 1988, the IAM reorganized itself into a fresh lineup to augment its technical potential in fundamental and initiative researches. By 1993 the agricultural mechanization promotion activity was partially modified to promote the overall development, realization, and effective utilization of high-quality agricultural machinery such as agricultural robots and vegetable machinery. "Urgent Development of Agricultural Machinery and its Commercial Enterprise", a five-year project, was carried out until 1997. As the result, the IAM developed new machineries such as the vegetable grafting robot, burdock harvester, new combine harvester for multi-crops, high-speed rotary tiller, and microcomputer controlled unmanned air blast sprayer grassland renovator, etc.

In 1998, a research development strategy for agricultural mechanization was established to promote and develop the machineries required under the current agricultural conditions, through the program "the new project towards 21st century (Urgent Project 21)" in partnerships with private companies, obtaining assistance from universities and public research institutes. The main object of this strategy is to develop a new machine for practical use in establishing a consistent power farming system, for contributing to agriculture in harmony with environment, and for reducing the farm work loads in hilly and mountainous areas. In this project, machinery research, and development and practical use are eagerly making a rapid progress.

Organizational Set up

Overall Organization

The overall organization of the present BRAIN and IAM Institute consists of a Tokyo office and the

IAM in Omiya city. The main functions of Tokyo office are as follows: ① To promote biotechnolgy and related industries through loans or investment to organizations affiliated to the private sector and local governments; ② To promote basic research activities for innovative biosciences through contract or collaborative research with research teams from universities, public institutions, and other research organizations. The total of BRAIN is 101, while the IAM has 81.

The IAM maintains an area of about 18 ha and runs an experimental farm with an area of 16 ha where many kinds of crops are grown for research and testing activities.

The IAM has four research departments, two research teams and testing and evaluation department for developing and testing agricultural machineries. Two research teams were newly established in 1993 for developing vegetable machineries under the "Project for the Urgent Development of Agricultural Machineries and their Commercial Enterprise". Research and test in each department are conducted in close contact with related governmental, prefectural and industrial research institutes.

The following show the organization and activities of these departments.

Planning Department

IAM's Planning Department is in charge of the management of varied activities. This planning department consists of the following divisions:

① 1st Planning Division (Tokyo office);
② 2nd Planning Division;
③ Machinery Information Division;
④ Executive Secretary for International Collaboration;
⑤ Executive Secretary for Industrial Property;
⑥ Executive Secretary for Research Information;
⑦ Vegetable Machinery Team 1; and
⑧ Vegetable Machinery Team 2

Technology Department

The five laboratories of the Technology Department are as follows:

① Agricultural Automation Laboratory;
② Biotechnology Engineering Laboratory;
③ Ergonomics Laboratory;
④ Machine Dynamics and Reliability Laboratory; and
⑤ Rural Resources Management Laboratory

Crop Production Machinery and System Department

The Crop Production Machinery and System Department aims at developing crop production machineries to increase the yield and working efficiency for paddy and upland farming. This department consists of the following laboratories:

① Soil Management Machinery Laboratory;
② Paddy Field Mechanization Laboratory;
③ Planting System Laboratory;
④ Crop Tending Machinery Laboratory;
⑤ Harvesting System Laboratory; and
⑥ Drying and Processing Equipment Laboratory

Horticultural Engineering Department

The Horticultural Engineering Department aims at developing machineries for horticultural and post harvest technology of horticultural crops. This department consists of the following laboratories and a workshop:

① Orchard Machinery Laboratory;
② Vegetable Machinery Laboratory;
③ Postharvest Technology Laboratory; and
④ Workshop for manufacturing, reconstructing and repairing machines for research and testing

Animal Industry Engineering Department

The Animal Industry Engineering Department aims at developing machineries and apparatus for the animal industry. This department consists of the three laboratories:

① Forage Crop Producing Machinery Laboratory;
② Feed Processing Machinery Laboratory; and
③ Livestock Raising Machinery Laboratory

Testing and Evaluation Department

The Testing and Evaluation Department consists of the following five divisions that carry out National Tests, Safety Tests, IAM Tests and OECD Tests:

① Large Tractor Testing Division;
② Small Tractor Testing Division;
③ Transplanter, Sprayer and Harvester Testing Division;
④ Grain Harvester Testing Division; and
⑤ ROPS Testing Division

Research and Development Activities

Strategic Research Schemes for Agricultural Mechanization

The food self-sufficiency ratio as well as the active arable land ratio are decreasing in Japan. Likewise, the number of farmers is decreasing and aging, rural areas are depopulated, farm products are increasingly imported, and consumers' needs are more diversified and more advanced.

Given this background, the IAM organized a development research strategy for agricultural mechanization that cover six subjects matter areas:

① Development of machinery for efficient production;
② Development of machinery for high quality and value of farm

products;

③Development of machinery to maintain and promote the natural cyclical function of agriculture;

④Development of machinery suitable for hilly and mountains areas;

⑤Development of technology for the safety of agricultural machineries; and

⑥Research on fundamental technology for agricultural mechanization

Details are given as under.

Important Notes

Development of Machinery for Efficient Production

Promoting machinery development for efficient production will help establish a consistent power farming system, improve farming process, and reduce farm work load. It is necessary to improve the food self-sufficiency ratio, strengthen our international competitiveness, secure and foster a workforce for effective management, and supply farm products to consumers at reasonable and acceptable prices.

We must establish a new productive system, together with breeding of crop varieties suitable for machinery- and development of farm power technology. We will promote the mechanization of farm work in vegetables and fruits production. We will also improve the efficiency and multi-functionality of agricultural machinery, which will contribute to labor saving and cost reductions for crop.

① Machinery for farm labor saving and the establishment of a new production system - It is necessary to develop a head-lettuce harvester and roll baler for chopped tall forage crops like maize. This will help establish a consistent farm power system and reduce work load, since it will save labor and improve productivity, thus increasing the farmer's income. We must also develop harvesting aids for citrus fruits, and machines for fruit-vegetable harvesting and transportation.

② Machinery for low-cost production - We must design various kinds of agricultural machineries and promote multi-functionality. It is important that we develop an automatic straight operation system for agricultural vehicles, which will help cultivation and seeding, and develop a high-speed paddler-leveler, with the same accuracy as the existing one. A device must be installed for both transplantation and direct seeding, and we need an equipment for raising large amounts of quality seedlings.

Development of Machinery for High Quality and Value of Farm Products

It is important that future agricultural developments in Japan promote production efficiency and reduce production costs. We must correctly assess the consumers' needs, get an overall view of the entire process from production to shipment and consumption, and promote the high quality and high value and safety of farm products. It is important to improve consumption by improving the features of home grown farm products.

We must improve the accuracy of machinery operation and develop machines for the production and control as well as for distribution and storage, which will contribute to the high quality and value of farm products in pre/post harvest stages. Machines for quality estimations of farm products are needed. We can better estimate the quality of agricultural products by using technologies on both external and internal quality evaluation.

① Machinery for farm products with high quality and value - We should create a grain processor for high-quality and value. This processor will consist of a grain dryer incorporating an infrared radiator and a centrifugal rice huller, and will work as a dryer, a huller, separating and cleaning machine. We urgently need to design a processing device for soft leaf vegetables (such as spinach) that will cut the base of soft leafy vegetables and pack them or gather them in a bundle. We must also develop a selective harvester for vegetables, a combine harvester for high-quality crops, and a machine/device for drying, processing, storing, and packing.

② Machine to evaluate farm product - We can extend the application limit of nondestructive sorting machines to examine the internal quality of fruit by using optical sensors and acoustic sensors, and we should build a machine to detect the proper harvest time and to evaluate the storage conditions.

Development of Machinery to Maintain and Promote the Natural Cyclical Function of Agriculture

It is important to reduce chemical fertilizers and other agricultural chemicals in order to reduce environmental problems. It is also important to promote the effective use of resources such as bio-energy, agricultural by-products and waste.

We must develop machines for agricultural production that are in harmony with the environment and that can maintain and promote natural cyclical functions of agriculture, and machines for the effective use of resources.

Machine to reduce applications of fertilizers and other agricultural chemicals - By dividing a field into blocks and obtaining information regarding the conditions of the soil and the crops for each block, we can spread the minimal amount of fertilizer and chemicals necessary for insect and disease control, thus reducing environmental impacts. An operation navigator for agricultural vehicles is necessary to establish precision farming and thus increase yields, promote quality, and reduce cost. The navigator obtains information regarding the operating position as well as data of the soil and crops. A simplified device for on-the-spot soil analysis and a site-specific soil sampler are required. Furthermore, we must develop a system to gather information on the rice harvested grains by combine harvester.

An in-soil spot fertilizer applicator for orchards that would spread fertilizer more efficiently is required. We also must design a riding-type mechanical weeder and thereby reduce the use of agricultural chemicals. Dust-proofing and deodorizing systems to exhaust the air from livestock barns are needed to improve the livestock environment. A low-volume sprayer should be developed for upland crops.

Machines to reuse agricultural resources - Machines that require the use agricultural by-products effectively such as biomass and fertilizer from livestock manure. This will contribute to agriculture in harmony with environment. For example, we could develop a highly precise solid-liquid separation system, an automatic agitator to manage compost quality, and a compost system using natural energy. Moreover, we could develop a machine that uses alternative fuels by micro-emulsification of animal and vegetable oils.

Machine to control global warming - We urgently need to develop technology to reduce the exhaust from agricultural machine engines. We must design a hybrid agricultural machine in which both the engine and the motor work to control the discharge of greenhouse gasses. We must also endeavor to fabricate a device that uses a clean energy source such as the wind and or sun and does not directly discharge greenhouse gasses.

Development of Machinery Suitable for Hilly and Mountainous Areas

Hilly and mountainous areas account for 40 percent of the cultivable areas, farm households, and agricultural gross production in Japan. Although these areas play an important role in agriculture in Japan, their agricultural productivity is low since cultivation is difficult, there are fewer and older farmers, and machinery use is restricted. It is important to improve farming by effectively using the features of hilly and mountainous areas. We must develop machines suitable for hilly and mountainous areas; machines that will bring profits from special local farm products.

Machine suitable for small scale field and slopedlands - A head-feeding combine harvester that is suitable for small fields in hilly and mountainous areas and that can be transported by a small pick-up truck is needed. We must develop a multipurpose vehicle for hillside orchards that can be used for spray and transportation, a multipurpose mono-rail transporter for orchards on sloped lands, and a multipurpose tractor for sloped grasslands.

Machine for regional and special crops - We need a lotus root harvester, a sizing machine for capsicum, and a "konnyaku" collector and transporter in order to promote production of regional and special crops, which bring substantial profits.

Development of Technology for the Safety of Agricultural Machinery

The current major problem with agriculture in Japan is the weakness of the workforce, which is worsening as farmers age and fewer school graduates become farmers. This situation requires careful assessment considering the safety and protection of the operator's health, reducing the work load, and improving operating machineries.

We must advance technology for safe farming and establish methods of analyzing and estimating work loads. These will promote the development and improvement of machinery and equipment for comfortable work and work load reduction.

Safety technology - We must create an agricultural accident report system for collecting, analyzing, and presenting accident data. It is important to first simulate agricultural machine operations and assess the safety of technologies.

Technology for amenity and reduction of farm work - A monitoring and evaluation system is needed for the working environment and the work loads, which will contribute to assessing the ease of farm work. We propose creating a guideline for the reduction of agricultural work loads, especially the work loads of elderly people and women.

Research on Fundamental Technologies for Agricultural Mechanization

Scientific technologies, including automatic and intellectual technologies, information technology, and detection technology, have been developing very rapidly with the emphasis on IT technology. It is very important for the agricultural conditions in Japan to promote effective research development by applying advanced technologies to individual agricultural machinery developments.

We work in fundamental research which contributes to agricultural machinery development. An example is research on utilization of advanced technology, research on agricultural robots, and research on detection of bio-information.

We also conduct research on agricultural machinery with regard to multiple uses, reducing production costs and extended use, the establishment of reuse system for resources.

Moreover, we develop and promote testing and evaluation methods for agricultural machinery, and we develop support systems to use test data of agricultural machinery and to apply safety information.

This leads to effective development of agricultural machinery.

Research on autonomous operation systems using automatic control and recognition - We advise developing element technology for sensing within-field variability, and for actuation and control of machines. We propose automation and intellectualization of the total machine system and research on agricultural robots.

Research on applied technology of detecting information on plant growth and environment - Technology is required to detect environmental information: for example, the water, nutrition, disease and insect conditions within the fields.

Research for cost reduction and reuse of agricultural machines - We must develop agricultural machines which are easy to inspect, maintain and repair and should also design parts to be reused for agricultural machines.

Research for support of technology - Technological information about agricultural machines must be collected and analyzed. A safety information database and a database for the results of the researches and tests could be established by using extensive information networks. We recommend effective research on agricultural machines and the use of evaluation technology for them.

Modern advanced technologies enable us to develop and improve testing methods that will contribute to the development of agricultural machines. We can also create a processing system for measured data.

Moreover, we can establish models of these procedures to develop agricultural machines, analyze them, and distribute information about them.

The Project on "Urgent Development of Agricultural Machinery and It's Commercial Enterprise"

As mentioned above, the IAM worked to develop machineries under current agricultural conditions to promote this plan, through the project of from 1993 to 1997.

There are two types of projects: Urgent Development of Agricultural Machinery Project and Commercialization Promoting Projects. In these projects, the targets for high-performance agricultural equipment being researched and tested as well as the implementation methods are specified in the basic policies. Processes ranging from development to implementation are then integrated.

Urgent Development of Agricultural Machinery Projects

Commissioned development projects, joint R&D projects, etc. will be implemented for the high-performance agricultural equipment specified in the basic policies under the BRAIN initiative. These activities will be conducted through mutual cooperation of BRAIN and private sector organizations.

Commissioned development projects - These projects relate to agricultural machinery that requires urgent development. In some cases, development research responsibility will be assigned to private sector organizations with accumulated know-how. In other cases, the BRAIN will first perform the basic research then transfer the results of that research to a private sector organization.

Joint R&D projects - These projects also relate to agricultural machinery that requires urgent development, but development research will be performed joint by BRAIN and private sector organizations when both BRAIN and the private sector organizations have accumulated know-how.

Commercialization Promoting Projects

To promote the realization of high-performance agricultural equipment developed through Urgent Development of Agricultural Machinery Projects, an agent that has obtained the license for executing the plan from the Minister of The Agriculture, Forestry, and Fisheries will prepare basic manufacturing equipment such as dies and will standardize mechanized culturing styles. The New Agricultural Mechanization Enhancement Co., Ltd. Is licensed for this purpose and will promote operations according to the plan.

The New Project on "Urgent Development of Agricultural Machinery Towards the 21st Century"

From 1998 to the present time, after the project of "Urgent Development of Agricultural Machinery and It's Commercial Enterprise", we continuously work to develop the machinery through the new project of "Urgent Development of Agricultural Machinery towards 21st century (Urgent Project 21)". This is a five-year project from fiscal 1998 to fiscal 2002. IAM carries this project into execution through partnerships with private companies and by obtaining assistance from universities and public research institutes.

It is important that BRAIN, national experiment research institutes, universities, private and public experiment institutes, and other diverse organizations unite and cooperate in developing and improving agricultural machinery, and thus contribute to achieving the basic law regarding food, agriculture, and rural areas. It is crucial that we develop machines which can meet farmer's needs.

More precisely, we must consider the various opinions regarding the conception and planning of machinery development and reach an agreement about the development goals, including the machine prices. Furthermore, we must perform our research with a common goal.

We support the relationship between BRAIN's information regarding the development of machinery and the national/prefectures' information regarding power

Fig. 2 Walking type ridge mower.

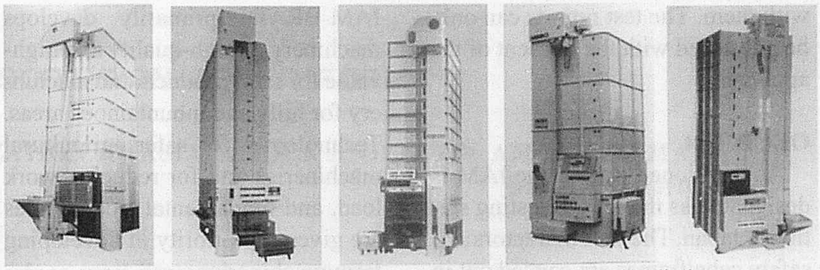


Fig. 4 Recirculating batch grain dryer using far-infrared radiation.

Fig. 3 Combine harvester for multi-crops.

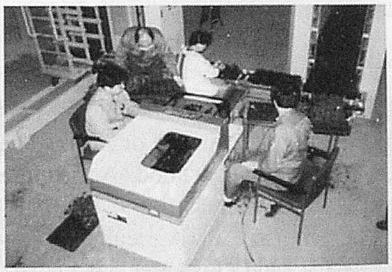


Fig. 5 Vegetable grafting robot.

Fig. 6 Cabbage Harvester.

cultivation methods and machinery work systems. We will adjust our development pace to that for power cultivation and systems research. We strongly advocate the introduction of machines after this development. We also establish research assessment system by external members and promote the development of effective research.

Given this background, we established a new "Urgent Project 21" for agricultural mechanization with the four machinery development objectives:

①Machinery for consistent farm power system

②Machinery for maintaining and promoting the natural cyclical function of agriculture;

③Machinery suitable for hilly and mountainous areas; and

④Fundamental technology for agricultural mechanization.

Figs. 2 - 8 shows several models of farm machineries developed under "Urgent Project 21"

Testing Activities in IAM

IAM's Testing and Evaluation Department carries out various tests of agricultural machinery. Further more, this department conducts research on development of testing and evaluating methods, including improvement of installation for testing, as well as on data processing in relation to evaluating activities. The following briefly describes the activities of various tests.

National Test

The National Tests are carried out in compliance with the Agricultural Mechanization Promotion Law, to determine performance, durability and operations of current machineries models. The kinds of machinery to be tested, testing codes and standards are determined and announced by the Ministry of Agriculture, Forestry and Fisheries. The test results are reported to the Minister, and the name of the approved models and the outline of their test results are made available to the public.

Safety Test

The Safety Tests are conducted on the basis of the rules prepared by the Safety Testing Advisory Committee to determine whether the machines tested meet the safety requirements or not.

IAM Test

The IAM Tests are conducted on

Fig. 7 Microcomputer controlled unmanned air blast sprayer.

Fig. 8 One-pass type grassland renovator.

the basis of our Test Regulations. There are Group1 Tests and Group 2 Tests in IAM Tests.

The Group 1 Test is carried out according to our test codes. The test is applied to important machinery selected by IAM. The evaluation reports are made available to the public.

The Group 2 Test is mainly conducted for manufacturers according to the test procedures agreed upon with them. The test reports can only be published with the consent of the applicants.

OECD Test

As mentioned earlier, the IAM is designated as the OECD testing station in Japan. The tests of tractors and safety cabs/frames are carried out in accordance with OECD standard codes.

Conclusion

The IAM-BRAIN has joined with private companies, university, and public experiment research institutes to develop farm power and related technologies according to the basic guidelines pertaining to policy for food, agriculture and rural areas. IAM-BRAIN primarily develops machinery of high-quality and high-value for farm products and machinery for hilly and mountainous areas. Technologies for safer agricultural machineries and for reducing work load, and fundamental technologies are given top priority in developing farm machineries.

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Institute of Agricultural Machinery: Institute of Agricultural Machinery Home Page, http://www.brain.go.jp, 2000 ■■

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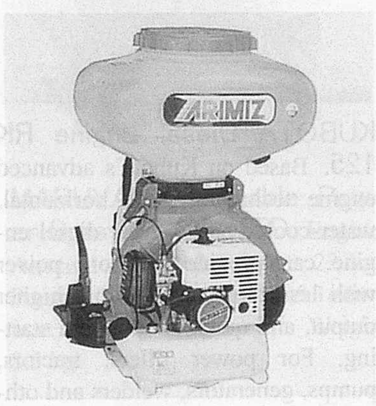
Main Production of Agricultural Machinery Manufactures in Japan

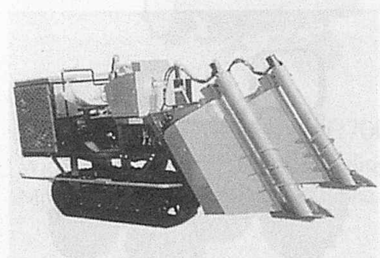
by
Shin-Norinsha Co., Ltd.
7,2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

Introduced here are the main products of agricultural machinery manufactures in Japan with a number of photographs.

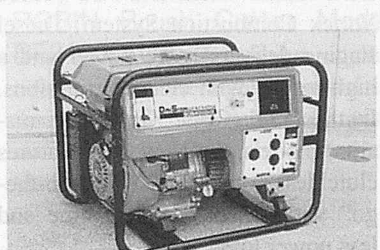
The products are developed and improved for both foreign and domestic markers. For further information please refer to the manufactures contained in the directory.



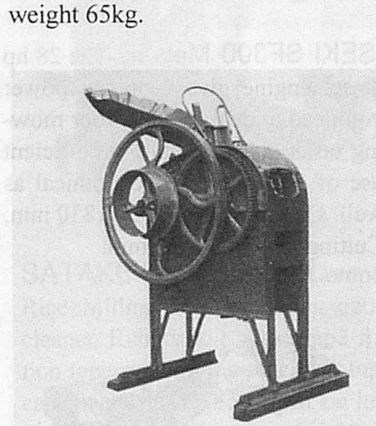
ARIMITSU Knapsack Power Duster Model SG-7030. Light-weight, compact design, but ensuring to produce bigger air volume due to high performance turbofan be driven by the powerful 60CC gasoline engine. Chemical tank can be quickly mounted or detached by menas of the lock or release lever. Size (L × W × H): 360Å~520Å~740mm, weight: 10.5kg, Max. output:3.7ps/7500rpm, Chemical tank capacity:28l, AIr volume: $140m^3$/min, Max. static pressure: 990 mm AQ.



BUNMEI Sugarcane Harvester Riding Type TK-5 Crop deviders equipped both sides raise fallen cane and give harvesting.



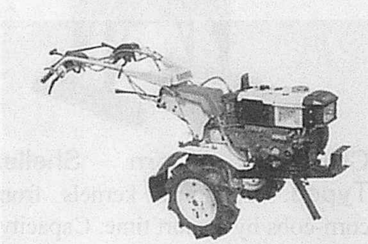
DAISHIN Portable Generator SGB4000HX. Brushless generator; Non-fuse breaker; Quiet operation; AC volage: (50Hz); (60Hz) Max.Output: (50Hz)3.6kVA (60Hz)4.5kVA.Engine: Air-cooled, 4-cycle,gasoline 5.2PS, 6.2HP;Dry weight 65kg.



CHIKUMA Corn Sheller Type3. Removes kernels from corn-cobs by a short time. Capacity: 750-1, 125kg/h, Power r'd: 1-2 PS, R.P.M.: 300-500, Size in mm: 1,015H × 575W × 1,010L, Weight: Net 90kg Gross 130kg, Shipping mess.: 18cft.

ISEKI TF325 Tractor. Mounted with powerful and economical 25PS water cooled diesel engine. The tractor offers wide range of travelling speeds from approximately 2 km/h to 22 km/h, which offers broad operating application and safe road travelling.

ISEKI SF300 Mower. The 28 hp diesel engine gives you the power you need to deal with all your mowing tasks quickly, while its efficient use of fuel makes it economical as well. Cutting width: 1524/1830 mm, Cutting height: 30-120mm.

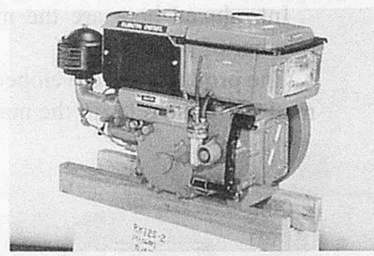


ISEKI Multi-Purpose Tiller KV700D. Four-cycle/direct injection/6PS engine allows heavy-duty operation at low speeds with ample power in reserve. Light, Compact, Easy to use and high performance.

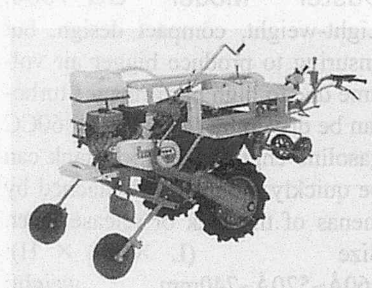
KIORITZ Battery-powered U.L.V.Sprayer(Shoulder type)ESD-5. A compact and lightweight battery-powered U.L.V. Sprayer providing easy portability combined with high performance. It is designed for use in environmental hygiene control such as malaria prevention, etc. in addition to general-purpose applications. Operates on six 1.5V batteries. A rechargeable battery pack can also be used.

KUBOTA Grand L Series Tractors. Built to handle a variety of agricultural applications, including field operations, heavy-duty front loader work. E-TVCS (Three Vortex Combustion System) Diesel Engine delivers more power and a high torque with cleaner emissions. In the GST (Glide Shift Transmission) models, the New GST features clutchless operation "shift-on-the-go" with faster response time and less power loss.

KUBOTA Combine Harvester SKY ROAD PRO 481. Easy to operate, micro-computerized 4-line combine harvester that cuts down on time as well as crops. Equipped with many helpful mechanisms and a reliable water-cooled diesel engine. Max. output: 48PS/ 27000 rpm.

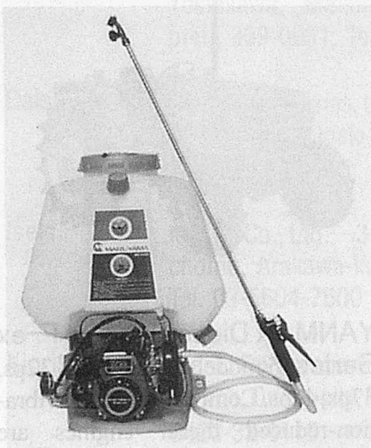


KUBOTA Diesel Engine RK 125. Based on Kubota's advanced engine technology, the horizontal, water-cooled and 4-cycle diesel engine can provide full-bore power with less fuel consumption, higher output, and quick and smooth starting. For power tillers, tractors, pumps, generators, welders and other farm and industrial used. Max. output: 12.5 HP/2400 rpm.

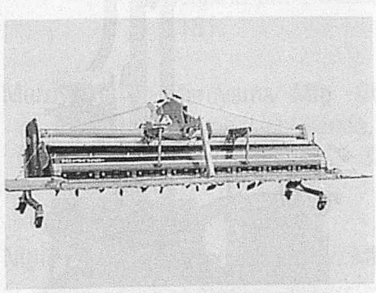


MAMETORA Vegetable Transplanter TP-4. This machine is available in both pot and soil block in seeding transplanting. Application: all vegetable nursery.

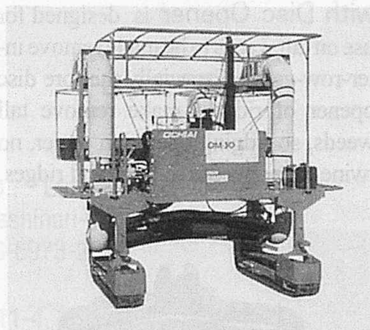
MAMETORA Power Cultivator SRV4F. Wide range use: cultivation to riding, Mounted with 7 PS engine.



MARUYAMA Portable Power Sprayers MSO55D. Engine: Air-cooled, 2-cycle, output 22.6cc, Pump: Suction capacity 5.1l/mm, max pressure 25 kg/cm^2. Weight: 8.5 kg.

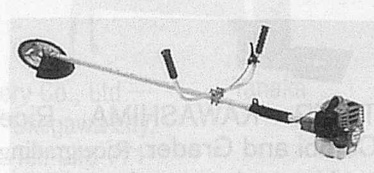


NIPRO Drive Harrow HR-2408B-3S for paddy field. Working width: 244 cm; Required tractor horsepower: 24-40HP.



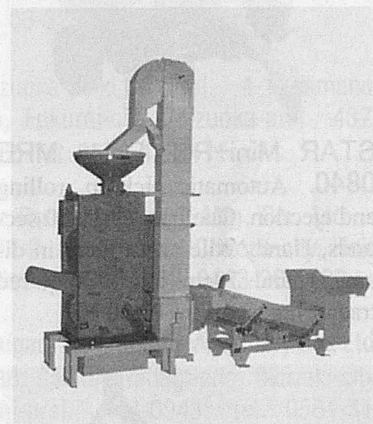
OCHIAI Riding Type Tea Picking Machine OM-30. Full working width cutter bar. Stepless speed control. Water-cooled Diesel engine 28.5PS

OREC Power Cultivator AR700. Wide range use: Cultivation to riding. Mounted with 7 PS ~ 7.5PS engine.



ROBIN Brush Cutter Model BF2100(AU). 2 cylinder engine (20cc) makes the lightest model in the wolrd and comfortable (low noise and vibration). Rotational speed of blade 4000-6000rpm.

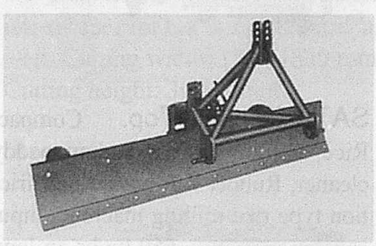
SASAKI Fertilizer Spreader BF-300. The lever type action controls the amount of application with high accuracy. Application width: 10-12m. Hopper capacity: 300l. Required tractor horsepower: 20-50PS.



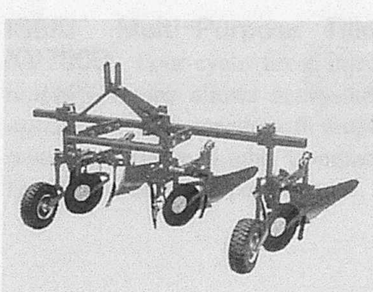
SATAKE Mill Top. Compact Rice Milling Unit including paddy cleaner, Rubber roll husker and friction type rice milling machine. Input capacity: Approx. 650 kg/hr on long grain rice. Required power: 25 PS engine (standard).

SHIZUOKA's Single Kernel Moisture Tester CTR-800E for rough rice, brow rice, wheat and barley.

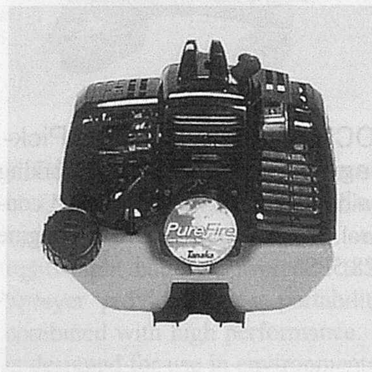
STAR Mini-Roll Baler MRB 0840. Automatic pick-up, rolling and ejection. One bale every 30 seconds, Handy bale size (50cm in diameter and 70cm long). Required tractor horsepower: 18-30 HP.



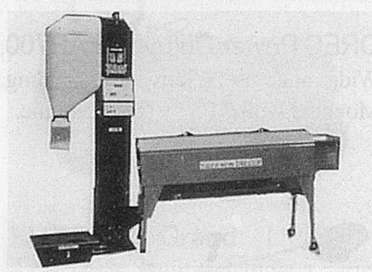
SUKIGARA Land Leveller-Model TL-MB/H3. A tractor is operated most effectively when the field has been uniformly levelled.



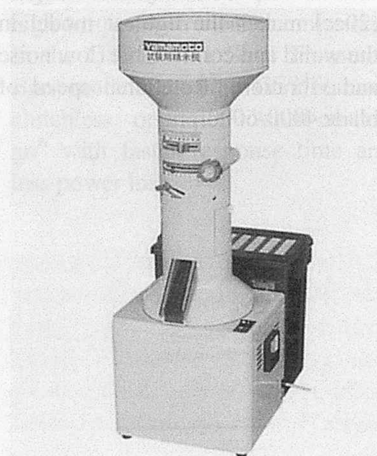
SUKIGARA Triple Row Ridger with Disc Opener is designed for use on tall weeds to be made remove inter-row-crops. Especially the fore disc opener of ridgers make remove tall weeds, so ridging operation easier, no twine round weeds to tines and ridges.



TANAKA 2-Cycle Engine Pure Fire is an environmentally kindly engine that cleared the secondary exhaust fumes control by the U.S. CARB. Both 26cc and 42 types are available. The engine just for the 21st century.

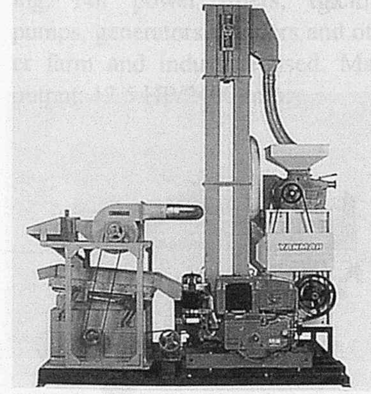


TIGER KAWASHIMA Rice Combi and Grader. Rice grading machine and automatic weighting and packing.



YAMAMOTO Rice WhitenerRicepal Series Model VP31T. High recovery rate. Immatured rice can be milled. No remaining rice in the machine. Easy-to-change milling screen. Durable construction. Milling system: vertical type single pass, Size (H × W × L): 850 × 330 × 450mm, Weight: 24kg, Power required: 0.3kW, Electric mains: single phase 100V (50/60Hz), Capacity: 30kg/h, Rpm: 1440/1730, Hopper holding capacity: 15kg, Safety device: Circuit protection.

YANMAR Diesel Tractor F-ex Series. 5 models: 21ps, 28ps, 32ps, 37ps, 42ps. Compact, quiet and vibration-reduced diesel engines are mounted at the heart of these F-ex series tractors. Engine: vertical, 4-cycle, water-cooled. Transmission: gear shifting. F8 × R8 or F9 × R9 Drive system. 4-wheel drive.



YANMAR New Mill Mate YMS-650U. Cleaner/destoner + Huller & Polisher + Engine. Input cap: 800kg/h, Engine 23ps. This machine is a complete direct-through rice mill consisting of a hulling section, winnower and polishing section. ■■

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The 11th International Conference and Exhibition on Mechanization of Field Experiments

(UK)

It is a great pleasure to express my appreciation to The Association of Applied Biologists for their kind cooperation with *IAMFE in organizing this IAMFE / AAB UK 2000 Conference and Exhibition on Mechanization of Field Experiments.*

This is our 11th International Conference and Exhibition during the 36 years since 1964 when the First International IAMFE Conference and Exhibition, IAMFE/ NORWAY'64, was arranged at the Norwegian Institute of Agricultural Engineering, Aas, Norway, and IAMFE was founded.

The objective of IAMFE is to assist agronomists, plant breeders and others in carrying out field experiments to increase the accuracy and capacity of their research work by mechanization. One important reason for the foundation of IAMFE was to assist agronomists and plant breeders in the developing countries to get suitable, high quality research equipment. This would enable the scientists to speed up the development of new and better varieties of crops and to improve the agronomic practices of the farmers.

Mechanization of field experiments should be introduced in cases where mechanization can increase the capacity and reduce the experimental error, so that new, resistant, high-yielding varieties and cultivation practices can be made available to the farmers in a shorter time.

Experience has shown that mechanization is the most efficient way to ensure that the work can be done rapidly and safely.

IAMFE has an obligation to assist the developing countries in their efforts to produce more food for a growing population and to help in avoiding erosion and pollution of the environment.

IAMFE is open to cooperation with all who wish to support the idea of international cooperation in the mechanization of agricultural research.

Let me tell you the story behind the establishment of IAMFE in 1964:

After the Second World War, the impact of mechanized farm operations started to reach agricultural research institutions. The gap between mechanization of farming and mechanization of field experiments became clear and was recognized as a problem that needed attention. An important reason for increased interest in mechanization of field experiments was also the shortage of manual labor encountered in many countries. These factors created the basis for a new science, "Mechanization of Field Experiments", and of specialized manufacturers of plot research equipment.

In 1958 the Agricultural Research Council of Norway therefore gave me a travel grant to study mechanization of field experiments in: England, Belgium, West-Germany, Denmark and Sweden. During 7 weeks I visited 27 research institutions and manufacturers.

I discovered that the research institutions within a country knew very little about the machinery, equipment and instruments used at other institutions in their own country. Between neighbour countries there were more or less an iron curtain. I also discovered that the manufacturers were very little interested in developing and manufacturing this kind of specialized equipment.

On the train between Belgium and Germany I started to think on the situation and came to the conclusion that "A European Institute on Mechanization of Field Experiments" should be established. In returning to Norway I started immediately to work for realizing this idea, I tried to get financing from FAO and OECD but was not successful.

In 1960 I went to USA with the purpose to study mechanization of field experiments and to try to find financing of the proposed European institute. I did not find the funding as I hoped. When I came back to Norway in 1962 I decided to arrange a European Conference on Mechanization of Field Experiments to get my "Plan for Efficient Mechanization of Field Experiments" discussed.

71 delegates from 17 countries participated in the event. United Kingdom, especially England, had a great delegation. Among the institutions represented where: Plant Breeding Institute, National Institute of Agricultural Botany, National Institute of Agricultural Engineering and Rothamsted.

Because of the great international interest in this Conference I introduced the sentence: "An International Association on Mechanization of Field Experiments should be established". This sentence was included in my plan only 2-3 weeks before the conference. It was not discussed with any others before my presentation at the conference.

As you have read in the beginning of this Preface, the delegates preferred IAMFE instead of The European Institute.

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BOOK REVIEW

Annual Report

JTI–The Swedish Institute of Agricultural and Environmental Engineering

(Sweden.)

JTI-The Swedish Institute of Agricultural and Environmental Engineering published their *Annual Report* for 1999.

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Dynamics of Vegetables Production, Distribution and Consumption in Asia

(Taiwan)

by Mubarik Ali

The economic, political, and social environments in Asia are fast changing. These changes include continuous increase in population and urbanization, increase in incomes, changes in agricultural input and output prices, development of physical infrastructure, such as roads, markets, and communication systems, and social infrastructure, such as education and training. On the food demand side, emphasis is now shifting from basic nutrients (i.e., calories and protein) to balanced diets (i.e., calories, protein. and micronutrients). This book enumerates these changes in the context of vegetable production, consumption, and distribution in 13 major vegetable growing countries of Asia. This chapter aggregates the individual country trends and draws conclusions at the regional level. Before proceeding, it is recommended to read Appendix i for explanations of the estimation procedures and terminology used in this book.

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Soil Erosion and Dryland Farming

A Worldwide Perspective on Erosion Control

(U.S.A.)

by John M. Laflen, Junliang Tian, Chi-Hua Huang

Overpopulation is at the core of most environmental problems. The impacts of continued growth--with world population reaching 6 billion in October 1999--are felt in most parts of the world. China, the most populous nation, illustrates many of the pivotal problems--and solutions.

Although China faces the same effects of overpopulation as the rest of the world, it still feeds over a billion people on a tillable area that allows about one tenth of a hectare per person. The country's efforts to tie together soil and water conservation, dryland farming, and economic development have been largely successful. Soil Erosion and Dryland Farming explores these trials and the lessons learned from them.

Copublished with the Soil and Water Conservation Society, this exhaustive text consists of the rewritten proceedings from the Society's conference held in Yangling, Shaanxi, China. It covers dryland farming systems and soil water management, environmental quality and sustainability, and erosion control techniques as they relate primarily to Mainland China. With additional global examples and a balance between conceptual and applied studies, it covers some of the most progressive work in soil erosion control and dryland farming from around the world.

Soil exposure while land lies fallow is one of the greatest risks in dryland farming. New procedures and kinds of tillage help control erosion and improve water intake.

Soil Erosion and Dryland Farming presents these techniques and technologies to give you a forward-looking perspective into the field, as well as the larger problem of tailoring food production to sustain the population.

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ABSTRACTS

The ABSTRACT pages is to introduce the abstracts of the article which cannot be published in whole contents owing to the limited publication space and so many contributions to AMA. The readers who wish to know the contents of the article more in detail are kindly requested to contact the authors.

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Effect of Reynold's Number of Drain Time of a Tank: Muhammad Iqbal, Assistant Professor, Department of Farm Machinery and Power, University of Agriculture, Faisalabad, Pakistan.D. F. Young, Professor, Department of Engineering Mechanics, Iowa State University, Ames Iowa, USA. Muhammad Younis, Lecturer, Department of Farm Machinery and Power, University of Agriculture, Faisalabad, Pakistan

This paper describes the experimentally developed relationship between Reynold's Number (Re) and drain time for 90% drain for a set of three geometrically similar tanks. The drain times were taken for the progressive combinations of 75% water /25% glycerin, 50% water/50% glycerin, 25% water /75% glycerins and 100% glycerin. The relationships behaved as a power law and SAS provided the best fit line. The research was carried out in the Laboratories of the Mechanical Engineering and Engineering Mechanics at the Iowa State University, USA. It was found that for the cut off value of $Re > 1120$ the pi term related to time behaved independently. Above this cut off value ($Re > 1120$) the Re effects were neglected and the length scale discrepancy was avoided in the model design. Moreover, for flows having $Re > 1120$ the theoretical solution appeared to closely predict the actual solution. The overall experiment results apply to the range of $1.5 < Re < 9300$.

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Interactive Behaviour of Active – Passive Tillage Tools Relative to Power Requirements: Dr. R. Manian, Professor, College of Agrl.Engg. TNAU, Coimbatore 641003, India. Dr. K. Kathirvel, Asst.Professor.

An active-passive tillage machine consisting of 16 rotor active elements and four passive elements with provision to change the depth of passive tool with respective to active tool and rotor speed was developed. Studies were conducted under controlled conditions (soil bin) in two extreme soils viz., sand and black clay loam by varying depth ratio (3 levels); rotor tip velocity (4 levels); and forward velocity (4 levels). The results obtained from the different combinations of active and passive tillage tools (5 levels) were computed and analysed. The following conclusions were drawn:

In both sand and black clay loam soil, wherever passive tool was involved either completely or partially, the role of depth ratio was significantly felt and its effect was adverse on draft power requirement. Rotor velocity was significant only in the case of active tool and accelerative on draft power. The forward velocity had adverse effect in both soils. Considering the maximum draft power reduction and number of trials in which the draft power of active + passive tools were less than that of passive tool, higher forward velocities of 1.06 and 1.53 m/s were recommended for sandy soil whereas the results were similar in the forward velocity range of 0.36 m/s to 1.53 m/s in black clay loam soil. In sandy, soil the torque required to operate the active tool increased as the forward velocity was increased to 0.7 m/s. Thereafter it decreased. As the rotor velocity was increased, the torque required decreased at all levels of forward velocity. In black clay loam soil also there was no increase in torque as the forward velocity was increased beyond 0.7 m/s. As the rotor speed was increased the torque required decreased. For all the active and active-passive tools combinations, both the rotor velocity and forward velocity were significant and the types of changes executed by the tools were almost identical.

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Design and Development of a Drier for Coffee: C. Karunanithy, Research Scholar, College of Agrl.Engg. TNAU, Coimbatore 641003, India. N. Varadharaju, Asst.Professor, same. R. Kailappan Professor and Head, same. K. Parvathy, Asst.Professor, same.

A batch type drier with 100-kg capacity was designed, developed and evaluated for coffee. The drying efficiency of 83.33% and HUF of 0.5 was achieved at an air temperature of 60 ℃ for a bed depth of 75 mm with an airflow rate of 2 m^3/min/ quintal of parchment.

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Biological Potential of Autumn Sugarcane as Influenced by Deep Tillage and Nitrogen Management: Muzzammil Hussain, Assistant Research Officer, Adaptive Research Farm, Vehari, Pakistan. Fateh Muhammad Chaudhary, Professor, Department of Agronomy, University of Agriculture Faisalabad, Pakistan.

The biological efficiency of sugarcane as influenced by deep tillage and nitrogen management were evaluated during 1995 and 1996 on a clay loam soil at the government Seed Farm, Vehari. The treatments comprising of cultivator, disc plough, chisel plough and subsoiler were tested at 0, 100, 200, and 300 kg N ha^{-1}. The combination containing chisel plough plus 300 kg N ha^{-1} produced maximum number of millable canes, weight per stripped cane and stripped cane yield. ■■

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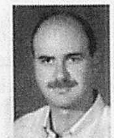
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h. Express measurements in the metric system and crop yields in metric tons per hectare(t/ha) and smaller units in kilogram or gram(kg/plot or g/row).
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j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
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(Vol. 30 No. 4, Autumn, 1999 ~)

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

(Vol. 31, No. 4, Autumn, 2000)

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