International specialized medium for agricultural mechanization in developing countries
ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.34, NO.1, WINTER 2003

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Edited by

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Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
URL : http://www.shin-norin.co.jp
E-Mail : ama@shin-norin.co.jp

SHIN-NORIN Building
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Printed in Japan

This is the 118th issue since its maiden issue in the Spring of 1971

EDITORIAL

A Case of War and Peace

As the 21st Century is upon us, one is reminded of a Japanese proverb that says, "Ten years make an epoch". An epoch indeed has been made as some 10 years back, the human race was happy in the thought that the world's peace then would continue to prevail. But alas, terrorism reared its ugly head in the 9/11 disaster in New York, the outbreak of war in Afghanistan, the fierce fighting in Chechnya, the current threat of nuclear war from North Korea and the impending war clouds in Iraq. But, of course, war is said to be a blight which erupts from time to time being a part and parcel of civilization. Once again, peace is being disturbed.

Although I have been repeating in this column that modern and speedy communication equipment and facilities have figuratively shrunk our world, population nonetheless continues unabated. In many developing and underdeveloped countries the rich become richer and the poor poorer - a silent case of war which is a big deterrent to the attainment of society's stability.

Back on the farm in most developing countries, the topsoil (and indispensable base for agriculture) is fast being lost to urbanization at the expense of rural dwellers whose basic source of livelihood is the farm and which, generally, depend on man and work animals for farm power. In contrast, it is the farm machinery that perform the menial farm tasks in developing countries. As an offshoot of this dichotomy, the rural youth shun the back-breaking farm chores and head to the cities instead. This situation is in itself a silent revolution as the aging farmers are left behind.

The preceding scenario is really one big reason why we, through AMA, keep harping about the importance of farm mechanization as the logical way to relieve the retiring farmers and the disappearing future farmers. Quite the truth is that farm machinery require much less manpower operators to do a lot much more farm operations.

War may come and war may go but progressive farming must necessarily be in peace in order to fulfill its task of producing food for both the vanquished and the victor.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
February 2003

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Feasibility of High-Speed Cultivation Device

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Abstract

From the review of literature, the data were collected to examine the feasibility (technical, economic and agronomic) of high-speed tractor-implement combination, by examining the requirements of soil/tractor, implement/soil and tractor/implement effects and proposing solutions to the present constraints. A 50-kW PTO tractor with 13-6/12-38 size rear driving wheel tyres had been chosen for conventional ploughing operation in average field conditions, with various rear axle weights and inflation pressures at 20% wheel-slip for maximum work rate. Then a high-speed tractor performance was examined at various ploughing speeds by altering the number of plough bodies and the width of cut, to match the conventional plough specific draught that obtained at conventional speed and the possible pull from the tractor for maximum work rate.

The high-speed, tractor-implement combination with light rear axle weight was predicted to result in higher work with fewer and narrower plough bodies, lower draught and wheel-slip in comparison with conventional tractor-implement combination with the maximum permitted rear axle weight. A semi-mounted plough attached to the free linkage was the feasible control system for high-speed tractor.

The predicted results indicated that a high-speed, tractor-implement combination is technically, economically and agronomically feasible.

Introduction

The history shows that the development of plough was dependent on cut-and-try method through the centuries. The development started when human effort was the only energy available to be used. Animal power was later introduced to drag the plough. Animal power was subsequently replaced by mechanical power for ploughing. The source of this power is the tractor which when produced had much more specific weight compared to the modern pneumatic tractors which show an increase in the drawbar power.

The drawbar pull required for the utilization of the available drawbar power is inversely proportional to the speed (Inns and Kilgour, 1978) as follows:

$$P_f = F_x \cdot V \qquad (1)$$

Therefore, a given drawbar power can be fully utilized in three ways: either by increasing the drawbar pull and keeping the speed constant, or by increasing the speed with low drawbar pull; or by increasing both the drawbar pull and speed.

The work rate of a 2-furrow plough can be increased by 50%; either by using a 3-furrow plough at the same speed. This needs an increase in tractor weight, engine power and cost of about 50%, or to increase the ploughing speed of the 2-furrow plough by 50%, which needs an increase in engine power of about 60% and 10% increase in weight (Sohne, 1960). At a given speed a wider implement with a powerful tractor will result in greater output but it is less maneuverable, gives greater variation in ploughing depth on uneven ground and loss in ploughing time at headlands, and also may result in steering problems as the result of far line of draught from center of pull. However, under conditions of using one conventional plough bottom for low draught and high speed, the cost of fuel per unit area will be greater and total costs high. Also, using wider implement and low speeds, the fixed costs of the plough and heavy tractor are greater and then total costs would be high. There was an optimum combination of speed and draught which resulted in a minimum cost (Barnes, 1960), and there is an optimum width of working for each machine (Barnes and Link, 1958). They found that the field efficiency of larger machines was low due to the time spent on turning at ends. Lehoczky (1967) discussed that the weight of tractor can remain unchanged when the work rate increased by ploughing at higher speeds. Certain conventional ploughs can be used at 8 km/h at which the yield was increased, but the deterioration in quality of work about this speed resulted in yield reduction. The conventional plough bodies do not stay in the ground at high speeds, therefore, high-speed bodies are required for work at 8-16 km/h (Culpin, 1976).

Trials were made to develop mouldboard plough for high speeds. Sohne (1959), Sohne and Moller (1962) performed experi-

Table 1. Tractor Tyre Performance on Average Field Conditions

Tractor rear axle weight (KN)	26.88	31.40	34.32	39.04
Recommended inflation pressure (bar)	0.8	1.1	1.3	1.6
Tractor possible pull at 20% slip (KN)	13.4	15.4	17	18.6
Driving wheels rolling resistance (KN)	2.6	3.2	3.6	4.2
Front wheels rolling resistance (KN)	0.5	0.6	0.7	0.8

mental work, which showed the difference in draught at various speeds for different types of conventional plough bodies. Sohne (1959) suggested that for high speed, plough bottom should be relatively flat, elongated, pointed and strongly twisted at the end of mouldboard wing in order to reduce the lateral movement of soil and higher towards the furrow side to prevent soil from being spread over it. This approach resulted in excessive mouldboard bodies dimensions in order to keep the lateral component constant to produce the same furrow shape and to reduce the draught. This was confirmed by Kermis (1978) who carried out a theoretical analysis by which a high-speed mouldboard plough can be designed up to any speed retaining the same performance of conventional plough at low speed. The length of the plough was found to be proportional to the speed. Another approach for high speed plough was studied by Lehoczky (1967) through investigations of ploughing at high speeds by conventional mouldboard ploughs, then a series of bodies were constructed having the same angle of attack but different share angles. The decrease in share angle was found to reduce the lateral movement of the soil. Then a high speed mouldboard plough was developed for satisfactory performance up to 11 km/h. The increase in the draught as a function of speed could be kept virtually constant by altering the plough bodies and a satisfactory ploughing could be obtained at any speed (Wainwright, 1976; Harral, 1976). McKibben and Reed (1952) and Barnes (1960) reported that a plough could be designed to give the desired furrow slice at any selected speed. However, the increase in tractor power and the eagerness of farmer to improve the timeliness in sowing dates are some factors in increasing the demand for high speed ploughing operation to increase the quantity and quality of the products.

Based on the previous research findings, the empirical equations were used to examine the feasibility (technical, economic and agronomic) of high-speed tractor-implement combination by examining the requirements of soil/tractor, implement/soil and tractor/implement effects and proposing solutions to the present constraints.

Prediction Procedure

Data were collected through literature review to examine the feasibility of high-speed tractor-implement combination in average field conditions, using a 2-wheel drive tractor with 50 kW engine power. The results obtained by Dwyer et al (1976) for 13.6/12-38, 6 ply rating tractor driving wheel tyre in average field conditions of 500 KPa cone penetrometer resistance were multiplied by 2 for 2-wheel-drive tractor and the results are shown in **Table 1**. The weights included the 20% permitted overload for each recommended inflation pressure for operation at speeds below 19 km/h. The 20% slip was chosen for continuous tractor operation at maximum pull. The raising of tyre inflation pressure with increasing weight is to prevent casing damage as the result of deflection which is limited to about 18-20% of the tyre section height (Inns and Kilgour, 1978). The rear axle weight shown in **Table 1** was assumed to be equal to the weight of the ballast, weight transfer and weight addition, which is equal to 80% of the total weight of the tractor-implement combination, and 20% assumed to be carried by the tractor front axle to maintain steering. The size of tractor front tyres was 7.50-16, with a diameter of 0.8 m and width of 0.2 m.

Gee-Clough et al (1978) used the tyre mobility number to predict the performance of a 2-wheel-drive tractor for optimum work rate as follows:

$$M = \frac{Cbd}{W} \sqrt{\delta/h} \left(\frac{1}{1 + b/2d} \right) \quad (2)$$

while the coefficient of rolling resistance was determined by using tyre mobility number as below:

$$C_{RR} = 0.049 + 0.287 / M \quad (3)$$

Equations (2) and **(3)** were mul-

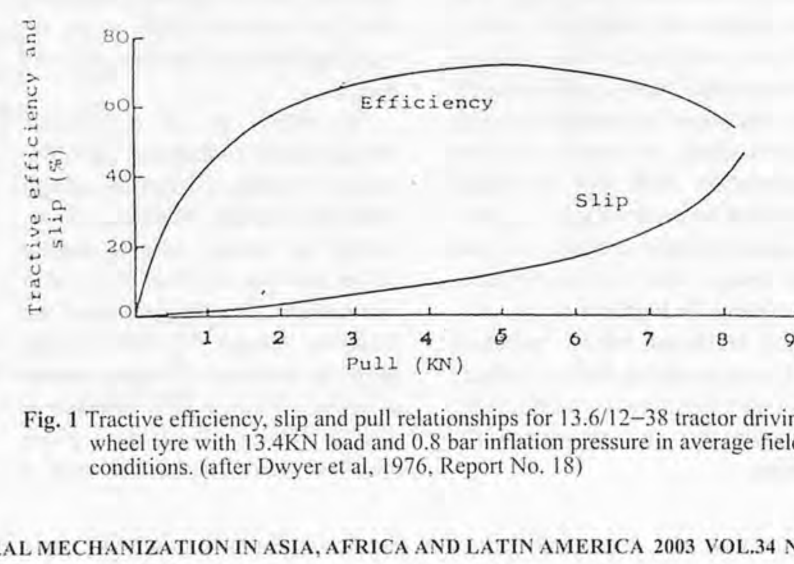

Fig. 1 Tractive efficiency, slip and pull relationships for 13.6/12–38 tractor driving wheel tyre with 13.4KN load and 0.8 bar inflation pressure in average field conditions. (after Dwyer et al, 1976, Report No. 18)

Table 2.Ploughing Operation Performance Prediction from A Conventional Speed Tractor-implement Combination

RAL (KN)	TS (m/s)	WS (%)	AS (m/s)	APP (KN)	UDP (kW)	NPB	WC (m)	UPA (m^2)	SD (KN/m^2)	WR (ha/h
26.88	1.96	20	1.58	12.9	10.7	3	0.40	0.24	54.0	0.54
26.88	2.50	20	2.00	12.9	4.0	3	0.35	0.21	61.0	0.61
26.88	2.81	20	2.25	12.9	/	3	0.32	0.19	66.6	0.63
31.40	2.43	20	1.94	14.8	/	4	0.31	0.25	60.2	0.69
34.32	2.19	20	1.75	16.3	/	4	0.36	0.29	56.8	0.72
39.04	2.00	20	1.58	17.8	/	5	0.33	0.33	54.0	0.75*

RAL = Rear axle load.
TS = Theoretical speed.
WS = Wheel slip.
AS = Actual speed.
APP = Available pull for ploughing.
UDP = Unused drawbar power.
NPB = Number of plough bodies.
WC = Width of cut.
UPA = Unit ploughed area.
SD = Specific draught.
WR = Work rate.
* = Maximum rate work.

tiplied by 20% of the tractor-implement-combined weight and the values are shown in the last two rows of **Table 1**.

Fig. 1 shows the relationships between tractive efficiency, slip and pull for a single 13.6/12-38 tyre size in the above mentioned average field conditions when the tyre was loaded by 13.4 KN and inflated by 0.8 bar inflation pressure (Dwyer et al, 1976).

Plough draught varies with the soil type, field conditions and the implement shape. Therefore, an average field condition similar to the field where the tractive performance of 13.6/12-38 tyres under different weights and inflation pressures were tested was selected from 14 field conditions used by Gee-Clough et al (1978) to predict tractor-plough field performance. The selected average field is sandy clay loam with stubble surface, 19.1% moisture content, 15.7 KN/m^2 specific weight and 602 KPa cone penetrometer resistance. This specific weight was assumed to be the same as the field of 500 KPa cone penetrometer resistance, since it was not determined when the tyre tests were carried out by Dwyer et al (1978). However, if the specific weight is different, it does not affect the calculated results, since it is a constant. This assumption was made to facilitate the use of the following equation (Gee-Clough et al, 1978):

$$D/aw = 13.3va + 3.06vV^2/g \quad (4)$$

For prediction of ploughing operation performance, the following equations were used (Inns and Kilgour, 1978):

$$V = V_n(1 - S) \quad (5)$$

$$P_t = P_e(1 - \eta_t) \quad (6)$$

$$P_s = P_d - S \quad (7)$$

$$P_r = R \cdot V \quad (8)$$

The available tractor drawbar power was determined by the following:

$$P_f = P_e - (P_t + P_s + P_r) \quad (9)$$

The available tractor drawbar pull was determined by dividing the available drawbar power by the actual speed to be as follows:

$$F_x = P_f/V \quad (10)$$

If the available drawbar pull is greater than the possible pull from the tractor driving wheel tyres, then the required power was determined by the following:

$$P_q = F_t \cdot V \quad (11)$$

Then the required power was subtracted from the available drawbar power and defined as unused drawbar power.

When the available drawbar pull was found to be less than the possible pull from the tractor tyres, the corresponding slip was determined by using **Fig. 1** and then the actual speed for the adjusted slip value was determined using equation (5). This procedure was repeated for all available drawbar pulls less than the possible pull from the tractor driving wheel tyres (sample of calculation is presented in Appendix 2).

The conventional plough specific resistance was predicted by **equation (4)**.

The rolling resistance of the front wheel tyres was subtracted from the possible pull from the tractor driving wheel tyres to give the available pull that could be used in the ploughing operation. Then equating the draught of the plough to the available pull for the determination of plough width of cut as **equation (12)**

The tractor work rate was determined according to Hunt (1979) as follows :

$$\text{Work rate (ha/h)} = V(wn)\frac{E(3600)}{10000} \quad (13)$$

The fuel consumption was considered in the economic analysis according to A.S.A.E. data (1980). The diesel fuel consumption in L/kW-h for 80% field efficiency was estimated by the equation (14).

The fuel consumption for 20% of each hour was assumed to be a 3rd of full load fuel consumption (Wilkins et al, 1971).

The conventional and high-speed ploughing operation performances with the same tractor were compared. The following facts were considered for the analysis:

1.A tractor with 50 kW engine power was used in the analysis for the ploughing.
2.Transmission efficiency(η_t) = 90%
3. Field efficiency (E) = 80%
4.Theoretical ploughing speeds below 19km/h was chosen to determine the maximum work rate that could be obtained at actual speed.
5.Wheel-slip was assumed to be 20% at speeds up to full utilization of the available drawbar power.
6.Depth of ploughing was kept constant at 20cm.

$$F_t - R_f = 13.3va^2\,(wn) + 3.06va\,(wn)\,V^2 / g$$

equation (12)

$$\text{Fuel consumption (L/kW–h)} = 2.64y + 3.91 - 0.2\sqrt{738y + 173}$$

equation (14)

Table 3. Ploughing Operation Performance Prediction from A High-speed, Tractor-implement Combination with 26.88 Kn Tractor Rear Axle Weight

TS (m/s)	WS (%)	AS (m/s)	APP (KN)	UDP (kW)	NPB	WC (m)	UPA (m^2)	SD (KN/m^2)	WR (ha/h)
1.96	20	1.58	12.9	10.7	3	0.40	0.24	54	0.54
2.0	20	1.60	12.9	10.4	3	0.40	0.24	54	0.55
2.5	20	2.00	12.9	4.0	3	0.40	0.24	54	0.69
3.0	16	2.50	11.9	/	3	0.37	0.22	54	0.79
3.5	13	3.10	9.8	/	3	0.30	0.18	54	0.81*
4.0	10	3.60	8.2	/	2	0.38	0.15	54	0.79

* = Maximum work rate
TS = Theoretical speed.
WS = Wheel slip.
AS = Actual speed.
APP = Available pull for ploughing.
UDP = Unused drawbar power.
NPB = Number of plough bodies.
WC = Width of cut.
UPA = Unit ploughed area.
SD = Specific draught.
WR = Work rate.

7. The engine was run at full throttle and the available drawbar power would be utilized in the pull when the traction from the tyres was available.
8. The slip of each wheel was assumed to be the same by using differential lock (Gee-Clough et al, 1978).

Results and Discussion

The predicted results of conventional, high-speed tractor-implement performance and implement draught are shown in **Tables 2, 3** and **4** respectively.

The maximum work rate output of tractor-implement combination was taken as a reference for comparison of conventional and high-speed ploughing operation with the same tractor.

With the tractor rear axle weight of 26.88 KN, the speed of ploughing was found to be increased at a constant delivered pull of 12.9 KN from the tractor wheel tyres of 13.4 KN (**Table 1**). The speed was increased for complete utilization of the available drawbar power at 20% wheel-slip according to equation (1) for both conventional speed (**Table 2**) and high-speed tractor-implement combination (**Table 3**). For conventional speed, the rear axle weight was increased up to the maximum permitted weight at reduced speed. The width of plough was determined by equation (12). The number of plough bodies and the width of cut were varied according to the available pull for ploughing operation.

The specific draught of conventional plough was determined by equation (4) (sample of calculations is presented in Appendix 1), which was obtained to be 54 KN/m^2 at ploughing speed of 1.58m/s (5.7 km/h) for both rear axle weights of 26.88 and 39.04 KN. The maximum work rate of 0.75 ha/h was obtained when the tractor rear axle was loaded to the maximum weight of 39.04 KN, with the use of 5 plough bodies, each was of 0.33 m width of cut, resulting in 0.33 m^2 unit ploughed area.

Table 4. Predicted Implement Draught with The Speed for Conventional and High-speed Ploughs

With conventional plough			With high-speed plough		
Rear axle load (KN)	Actual speed (m/s)	Draught (KN)	Rear axle load (KN)	Actual speed (m/s)	Draught (KN)
26.88	1.58	13.0	26.88	1.58	13.0
26.88	2.00	12.9	26.88	1.60	13.0
26.88	2.25	12.7^F	26.88	2.00	14.8
31.40	1.94	15.1	26.88	2.50	15.9^F
34.32	1.75	16.5	26.88	3.10^A	15.9
39.04	1.58^A	17.7	26.88	3.60	15.9

^A = Actual speed for maximum work rate.
^F = Draught at full utilization of available drawbar power.

One of the prerequisites of high-speed tractor is the lightweight of the rear axle. The speed of 1.58m/s (5.7 km/h) was assumed to be the conventional speed at which the plough performs satisfactory. This is because there is no definite speed but there is a feasible range of speeds at which a plough can give an acceptable quality of work depending on the amount of trash, soil type and soil moisture content. However, the specific draught or the soil resistance per unit area of furrow section as defined by Culpin (1976) depends on the plough design and type and the field conditions. The specific draught at conventional speed should be kept constant for the high-speed plough. The feasible solution for that is by altering the number of plough bodies and width of cut.

Therefore, the predicted results of high-speed, tractor-implement combination and the maximum work rate are shown in **Table 3**. After full utilization of available drawbar power, the speed was increased at reduced delivered pull from the tyres with reduced wheel-slip. The calculated corresponding slip for available drawbar pulls less than the possible pull from the tractor is shown in Appendix 2. The maximum work rate of 0.81 ha/h was obtained at ploughing speed of 3.1m/s (11 km/h), using 3 bodies and each body was of 0.3m width of cut, resulted in 0.18 m^2 unit ploughed area and 13% wheel-slip.

The following relations affect the ploughing operation performance:

1. *Soil/tractor Relation*

This relation represents the tractor traction. For a certain amount of weight on the tractor driving wheels and recommended inflation pressure, there is a certain amount of pull that can be delivered from the tyres, which can be used in pulling a plough in the ploughing operation as shown in **Table 1**. At low speed and for the ploughing operation at 20% wheel-slip the drawbar power available is more than that required for the ploughing operation due to the limitation imposed by the maximum possible pull that can be delivered from the tyre (see Appendix 1). The predicted results in **Table 2** show that with light rear axle weight of 26.88KN and conventional plough, in spite of increased implement specific draught, the work rate was increased with the speed up to the full utilization of the available drawbar power at 2.25m/s actual speed. Then the increase in the rear axle weight of the tractor increased the delivered pull from the tyres for the ploughing operation to give the maximum work rate with maximum permitted rear axle weight and reduced speed.

At low speed a high drawbar pull is desired which requires a big load on the driving wheel tyres through the ballast and weight transfer and addition that necessitate big tyres. The big load has a serious effect on the soil compaction, especially under conditions when the soil renders it.

The feasible solution for the tractor to utilize the engine power efficiently and without increase in the weight is by operating in higher gears. **Table 3** shows the predicted results of high-speed tractor-implement combination with light rear axle weight (26.88 KN). The full utilization of available drawbar power occurred at 2.5 m/s actual speed and 16% wheel-slip. The predicted work rate was increased at an increased speed to give higher work rate of 0.81 ha/h at higher speed (3.1 m/s) with reduced pull (9.8 KN) and wheel-slip (13%). The reduction in the work rate below 0.81 ha/h was due to the power loss in overcoming the rolling resistance at increased speed when equation (8) was used. The rolling resistance that may cause soil compaction was found to be reduced with the speed. The increase in the speed from 1km/h to 9km/h resulted in 30% reduction of soil compaction (Dwyer et al, 1976). The reduction in wheel-slip increases the available drawbar power and working time for the useful work, with higher tractive efficiency whereby a higher work rate could be obtained (**Fig. 1**). The reduction in wheel-slip with the increased speed for the high-speed tractor, could be explained by the investigation in the following formula (Reece, 1967):

$$J_m = Sl \qquad (15)$$

This shows that the soil displacement (J_m) is a function of time as the shear deformation grows from zero at the front to maximum at the rear. At high speed the time of tyre contact with the soil will be less than at low speed, resulting in less soil deformation. As the length of tyre contact (l) is constant then the only variable to be reduced is the slip (S). The light tractor rear axle weight would result in less soil compaction and facilitate the ploughing operation in less favorable field conditions. This would lead to improve in timeliness of sowing date.

For higher speeds, the drawbar pull will be less than the possible pull from the tractor tyres. The limiting factor is the available drawbar power that could be utilized in the ploughing operation and not the available traction from the tyres (**equation 1**). On the other hand, an increase in the speed with low drawbar pull requires a low amount of ballast, narrow tyres which reduce the soil compaction and facilitate the operation under adverse conditions to improve the timeliness, where the heavy tractors can damage the soil structure. Therefore, as a result of the drawbar pull reduction, the wheel-slip would be reduced.

2. Implement/soil Relation

This relation represents the implement draught, which was determined by the following equation that was derived from equation (4):

$$D = 13.3va^2w + 3.06vV^2aw/g(16)$$

The term (aw) represents the unit ploughed area by the plough. The results of implement draught for conventional and high-speed ploughs with the speeds are shown in **Table 4**.

For the conventional plough and the same rear axle weight of 26.88KN, the implement draught was reduced with increased speed. This was due to the reduction in plough body width of cut and, consequently, the reduction in unit ploughed area for the same number of plough bodies (3 bottoms) (**Table 2**). This occurred up to the full utilization of the available drawbar power. Then the implement draught was increased with an increased rear axle weight. The maximum work rate of 0.75 ha/h (**Table2**) was obtained at higher implement draught of 17.7 KN (**Table 4**). While for high-speed ploughing operation with the light rear axle weight (26.88 KN), the unit ploughed area was constant with constant plough width of cut up to the full utilization of the available drawbar power. Then the width of cut was reduced with the increased speed (**Table 3**). The maximum work rate of 0.81 ha/h was obtained at 15.9 KN implement draught, which was 11% lower than that obtained with conventional plough.

3. *Tractor/implement Relation*

This relation represents the tractor control system. The two common types of plough attachment are trailed and mounted. The trailed type has transport wheels that add cost and increase draught through the rolling resistance compared to the equivalent mounted plough (Morling, 1979). This type of implement requires a heavier tractor compared to its power to pull the implement through stiff spots in the field at the depth set (Dwyer, 1974; Morling, 1979). With the mounted type on the three-point linkages, the linkages either to be restrained or free. With restrained linkages the tractor supports the implement completely or partially. The used control systems which are automatic position, automatic draught, pressure and traction control, are characterized by depth variation when the tractor traverses soil undulations (Morling, 1979; Kepner et al, 1972; Liljedahl et al, 1979; Bjerninger, 1958). This is because the implement behaves as if it is rigidly attached to the tractor. Also weight transfer and addition to the rear driving wheels to improve the traction and to reduce the slip at low speed and high pull characterize these systems. While with the free linkages, which has no force sensing system (Morling, 1979), the implement moves relative to the tractor about the point of links convergence, which is called virtual hitch point (VHP). This arrangement can give maximum weight transfer and weight addition by altering the geometry of links (Reece, 1956). When a depth wheel is used with this arrangement, the implement becomes a semi-mounted type. The depth wheel will limit the weight transfer. The function of draught control can be limited when the depth of the wheel is in contact with the soil and it does not maintain a constant draught with uniform wheel-slip on a leveled field surface with varying soil resistance (Skalweit, 1964). Harden (1962) considered the increase in tractor power with approximately the same stability moment will increase the demand for semi-mounted plough especially with steering gauge wheel to reduce the turning radius of tractor-implement-combination and with greater advantages than mounted plough for contour ploughing. Cowell (1967) found that the draught control system was unsatisfactory and deteriorated rapidly at speeds about 6.5 km/h with the tendency of the plough to run shallower. A satisfactory method of obtaining uniform depth of ploughing was by semi-mounted plough using depth wheel control and position control once the desired depth of ploughing was obtained (Gee-Clough et al, 1978). It was described by Kepner et al (1972) that a more uniform depth compared to the position control system or draught control system can be obtained when a mixture of free linkage and depth wheel running on unploughed land is used. The resultant pull passes through the VHP point, which coincides with the instantaneous center of rotation (ICR), at the convergence of the top and lower link (**Fig. 2**). Clyde (1954), Reece (1956) and Bjerninger (1958) discussed the effect of position of the VHP on the weight transfer to the rear wheels and the vertical soil force support on the depth wheel control. If the position of the VHP is high and to the rear of the tractor, the tractorís lift force will be greater than the load supported by the depth wheel (h_f bigger in value). If the VHP is lower and forward then the larger load is supported by depth wheel and less weight transfer from the front to the rear axle of tractor occurs. This is equal to ($F.h_f/e$) and less weight addition ($F = \sin Ø$). The low line of draught (h_f less in value) means longitudinal stability of the tractor and adequate steering. The depth of ploughing can be adjusted for each line of draught corresponding to the soil condition by altering the linkage geometry. Also the tractor top and lower links can be provided with rows of points for implement attachment (Reece, 1956).

The characteristics of high-speed tractor are the lightweight and a reduction in wheel-slip at increased speed. Therefore, a possible simple control system which gives low weight transfer and weight addition is the semi-mounted plough attached to the free linkage with low and forward VHP as shown in **Fig. 2**, with depth wheel control to give uniformity in ploughing depth on irregular and undulated field surface.

Economic Analysis

For high speed ploughing operation, The implement becomes narrower and fewer in number with a higher work rate (**Table 3**) in comparison with conventional ploughing operation speed (**Table 2**). These results agree with Wilkins and Coleman (1971) who reported that this would increase the market of small powered tractors than the heavy ones because the lifting capacity of the three-point linkage will serve efficiently with lighter weight implements. The higher field speeds result in lower capital investment, simplified transport that results in savings of production line, compact field units and simplified implement servicing.

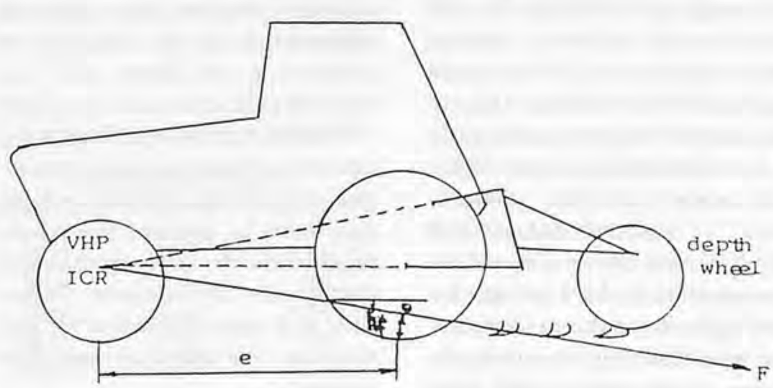

Fig. 2 The coincidence of VHP and ICR with free linkage and depth wheel control system.

The wheel-slip that occurs when a conventional tractor working in a soil with high moisture content will cause smearing that forms a hard layer when it dries up. This will limit penetration of plant roots, prevent aeration and gas exchange, which affect the microorganisms and cease their activities in decomposing the organic matter to increase soil fertility. Therefore, wheel-slip reduction with light rear axle weight and high-speed tractor will lead to an increase in soil fertility and hence an increase in crop yields. Also, the reduction in wheel-slip means the tyres will last longer with greater tractive performance (Gee-Clough et al, 1977) and increases the actual forward speed (**equation 5**). Therefore, increases the rate of work which leads to timeliness improvement and economic use of fuel.

The fuel consumption in l/ha was lower with high-speed tractor in comparison with conventional tractor speed, when the tractor was used to utilize all the available drawbar power, therefore:

Fuel consumption at 100% full load (**equation 14**) = 25.672 l/h

Fuel consumption at 20% full load (1/3 full load consumption) = 8.557 l/h

The average fuel consumption at 80% field efficiency = 17.115 l/h

Fuel consumption/ha at conventional speed = 22.82 l/ha

Fuel consumption/ha at high-speed = <u>21.13</u> l/ha

The saving in Fuel consumption/ha = 1.69 l/ha

In the United States there are 250 billion tons of soil to be ploughed each year that require 500 million gallons of gasoline costing $ 105 million. Therefore, a plough design that could reduce the draught by 1% would result in savings of $ 1 million per year (Agricultural Handbook No. 316). However, the higher-speed tractor-implement combination was found to reduce the draught by 11%, which means a savings of $ 11 millions per year.

A comparison of conventional and high-speed tractor-implement combination undertaken by Lehoczky (1970) reveals that the levels of repairs and replacement were the same, and an experimental work of ploughing operation up to 15km/h was attempted with satisfactory performance of work. This has indicated that the modern tractor design will facilitate the ploughing operation at high speeds.

Conclusion

1. With the conventional plough, the predicted increase in the draught with the speed was found to be the major factor in limiting the tractor output.
2. With high-speed, tractor-plough combination the predicted output of the tractor was found to increase with the speed up to 0.81ha/h with reduced wheel-slip and implement draught in comparison with the conventional one. Thereafter, the output was reduced as the result of power loss in overcoming the rolling resistance.
3. For high-speed ploughing operation, the implement bodies were predicted to be narrower and fewer in number.
4. The semi-mounted, high-speed plough attached to the free linkage is the feasible simple control system for high-speed ploughing operation.
5. A high-speed tractor-implement combination was predicted to be technically, economically and agronomically feasible.

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Appendix 1

Sample of Calculations

The following are predictions for a conventional speed tractor-implement combination when the tractor rear axle weight is 26.88 KN working in average field conditions at 1.58m/s ploughing speed and 20% wheel-slip:

$P_t = 50(1 - 0.9) = 5$ kW

$P_s = 45 \times 0.2 = 9$ kW

$P_r = 2.6 \times 1.58 = 4.11$ kW

The available drawbar power (P_f)= 50−(5+9+4.11) = 31.89 kW

The required drawbar power = 13.4 × 1.58 = 21.17 kW

Unused drawbar power = 10.72 kW

Then by applying equation (9), giving;

$$13.4 - 0.5 = 13.3 \times 15.7 \times (0.2)^2(wn) + 3.06 \times 15.7 \times \frac{0.2 \times (wn) \times (1.58)^2}{9.81}$$

$$12.9 = 8.35(wn) + 2.45(wn)$$

Therefore, $(wn) = \frac{12.9}{10.8} = 1.19$ m

Number of plough bodies = 3 bodies

Width of cut of plough body = 0.4 m

Unit ploughed area = 3 × 0.4 × 0.2 = 0.24 m²

The specific draught was determined by applying **equation (8)**, giving;

$$\frac{D}{aw} = 13.3 \times 15.7 \times 0.2 + \frac{3.06 \times 15.7 \times (1.58)^2}{9.81} = 54 \text{ KN/m}^2$$

$$\text{Work rate} = 1.58 \times 3 \times 0.4 \times 0.8 \times \frac{3600}{10000} = 0.54 \text{ ha/h}$$

The same procedure was applied for determination of other variables in **Table 2**.

Appendix 2

Sample of calculations for slip prediction less than 20% was carried as follows;

Actual speed for 3 m/s at 20% slip= 3(1 − 0.2) = 2.4 m/s

P_t = 50(1 − 0.9) = 5 kW

P_s = 45 × 0.2 = 9 kW

P_r = 2.6 × 2.4 = 6.24 kW

Therefore, the available drawbar power (P_f) = 50 − (5+9+6.24) = 29.76 kW

The available drawbar pull = $\frac{29.76}{2.4}$ = 12.4 KN

The available drawbar pull is less than the possible pull from the tractor. The corresponding slip to the pull of 12.4 KN can be found from **Fig. 1** for a single wheel (6.2 KN), which is= 16%

Then the adjusted actual speed = 3(1 − 0.16) = 2.5 m/s

P_t = 50(1 − 0.9) = 5 kW

P_s = 45 × 0.16 = 7.2 kW

P_r = 2.6 × 2.5 = 6.5 kW

Therefore, the available drawbar power (P_f)= 50 − (5+7.2+6.5) = 31.3 kW

The required drawbar power = 12.4 × 2.5 = 31.0 kW

Unused drawbar power = zero

Available pull for the ploughing= 12.4 − 0.5 (front wheels rolling resistance) = 11.9 KN

Unit ploughed area = $\frac{11.9}{54\ \text{(specific draught)}}$ = 0.22 m^2

The width of plough = $\frac{0.22}{0.2}$ = 1.1 m

Number of plough bodies = 3 bodies

Body width of cut = 0.37 m

Work rate = 2.5 × 3 × 0.37 × 0.8 × $\frac{3600}{10000}$ = 0.79 ha/h

The same procedure was applied for the determination of other variables in the last two rows in **Table 3**.

Notation

P_f = tractor drawbar power, kW.

F_x = the available drawbar pull, KN.

V = actual forward speed, m/s.

M = tyre mobility number.

C = soil cone index, KPa.

b = width of tyre contact, m.

d = tyre diameter, m.

W= load on the tyre, KN.

ä = tyre deflection under load, m.

h = tyre section height, m.

C_{RR} = Coefficient of rolling resistance.

D = plough draught force, KN.

a = depth of cut of plough, m.

w = width of cut of plough body, m.

i = soil specific weight, KN/m^2.

g = gravitational constant, 9.81.

V_n = theoretical forward speed, m/s.

S = wheel slip, dimensionless.

P_t = power loss in ground drive transmission, kW.

P_e = delivered engine power, kW.

ç$_t$ = transmission efficiency, percent.

P_s = power loss due to slip, kW.

P_d = power at the ground drive, kW.

P_r = power loss due to the rolling resistance, kW.

R = rolling resistance, KN.

P_f = available drawbar power, kW.

P_q = required power for pulling, kW.

F_t = possible pull from the tractor driving wheel tyres, KN.

n = number of plough bodies.

R_f = tractor front wheel rolling resistance, KN.

E = field efficiency, percent.

3600 = seconds per hour.

10000 = square meters per hectare (ha).

y = ratio of equivalent PTO power required by an operation to that maximum available from the PTO.

j_m = maximum linear soil deformation, m.

l = length of tyre contact, m.

L = liter.

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Experimental Research on Dynamic Friction Coefficients of Coated Rice Seeds

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Abstract

Three types of hybrid rice seeds, widely planted in Southwest China, were experimented on in this research. The major factors and their significant levels affecting the dynamic friction coefficients of coated rice seeds were determined by means of orthogonal experiments and analysis of variance. Using coated rice seeds can simplify the procedure for factory seedling nursery. The test instrument used in collecting and analyzing the data by a new sensor system and a single-chip computer, which resulted in high testing precision.

Introduction

China is now popularizing transplanting technology of rice seedlings cultivated in nurseries. Using coated rice seeds for factory seedling nursery is a creative, agronomic technology. Coated rice seeds are directly drilled on plastic plates. The plates are then delivered into nursery seedlings, in which good quality seedlings can be cultivated. Dibble-precision drilling is one of the key links in seedling nursery. Coated rice seeds of low moisture contents are useful in dibble, precision drilling. The dynamic friction coefficients in coated rice seeds (one of the major physical and mechanical properties) are basic data for parameter designs and performance analysis on drilling devices based on using coated rice seeds.

At present, the properties of common (non-coated) seeds were studied carefully. Examples of these seeds included rice seeds (Nurul Islam, 1987), beans and peanuts (Chung, 1989), peal millet (Jain, 1997), wheat (Molenda, 2000), and castor nut (Olaoye, 2000).

There are no standards for testing methods for friction properties. Until now different methods were used to test them, and can be divided into three types: tilting surface, horizontal surface, and rotating circle surface methods. For example, Olaoye, Molenda and Chung utilized these three methods to test dynamic friction coefficients of castor, wheat, and beans and peanuts separately. Among the three methods, testing instruments of the former two cannot easily let seeds relatively move on the friction surfaces at an even speed, which results in a bit of errors, and that of the latter one cannot conveniently test mini-torque on the rotating shaft.

Testing instrument in this research used the improved traditional instruments of rotating circle surface method, and collected and analyzed testing data using a new sensor system and a single-chip computer which resulted in high testing precision.

Materials and Method

Materials

Three common types of hybrid rice seeds were purchased from the Chongqing Seeds Corporation: IIyou838, IIyouduoxi57 and Gangyou22. These seeds were treated according to the requirements of factory seedling nursery (Qiu Bin, 2000 and Yang Mingjin, 2001) and testing arrangements.

Testing Method

The testing instrument in this research used an improved one. Data on testing are easily gained because the instrument directly tests dynamic friction force of seeds and not mini-torque on rotating shaft. **Fig. 1** shows a schematic diagram of the instrument. When testing, an alternating-current servomotor 6 leads friction circle plate 3 to rotate evenly. Seeds 8 (stuck on a small plastic plate) have a trend to move because of friction force. A rectangle beam sensor 4 (and the nylon line 9) keeps the seeds in the original position. The sensor then takes a bending stress and a bending deformation. The corresponding electric signal inputs a single-chip computer via differential amplified circuit. Dynamic friction force can be displayed on the screen after testing data is calculated and processed by the computer. Then the dynamic friction coefficients can be calculated as follows:

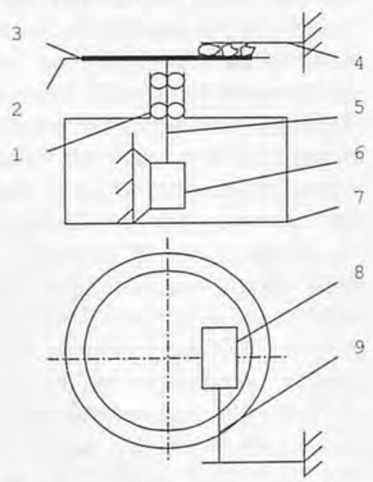
$f_d = F/W$

Where

f_d is dynamic friction coefficient,
F is dynamic friction force, and
W is weight of seeds (including weight of the small plastic plate).

The characteristics of the instrument can be summarized as follows:

1. Several seeds are stuck on a small plastic plate so as to reduce their rolling effects on dynamic friction coefficients.
2. Rotating shaft is double-supported on rolling bearings to reduce face runout effects of friction circle plate on the coefficients.
3. Alternating-current servomotor leads friction circle plate to rotate evenly which can reduce uneven velocity effects on testing data.
4. The shaft of alternating-current servomotor is softly bound to rotating shaft so as to help reduce the servomotor's vibrating effects on testing data.
5. The force sensor is manganese spring steel rectangle beam sensor with high sensitivity and good restitution.



Legend:
1. Roller bearings 2. Rotating plate
3. Friction circle plate 4. Rectangle beam sensor 5. Rotating shaft 6. Servomotor
7. Support 8. Seeds 9.Nylon line

Fig.1 Schematic diagram of testing instrument.

Experimental Plan

The major factors affecting the dynamic friction coefficients are seed conditions (coated or not), moisture contents, types of seeds and friction materials. Factor levels by means of orthogonal design arrangement, are shown in **Table 1**. Experimental arrangements are shown in **Table 2**.

Results and Discussion

Analysis of variance (Anova) results clearly indicated that the dynamic friction coefficients were determined by friction materials D, moisture contents B, type of seeds C and seed conditions A in a decreasing order of influencing significance level (moisture contents ranging from 10 to 20%db (dry basis)).

Furthermore, the Anova analysis was conducted to identify which factors significantly influenced the dynamic friction coefficients. **Table 3** shows that the friction material was the only factor that significantly contributed to the dynamic friction coefficients. The coefficients between seeds and steel with paint covering were maximum and minimum between seeds and PVC plastic for reasons that different frictional conditions between rice seeds and different friction surfaces prevailed.

Moisture contents had some effects on dynamic friction coefficients which increased with moisture contents. But the moisture contents of rice seeds ranging from 10 to 20%db (around safe storage moisture contents level) were quite low when drilled for factory seedling nursery, which reduced the level of significance effects on dynamic friction coefficients.

The types of seeds had a small effect on dynamic friction coefficients. Different kinds of rice seeds have different surface shapes which could affect friction conditions between rice seeds and friction materials. But testing samples in this research were screened according to the requirements of factory seedling nursery as cited earlier. Thus, the plump extents of seeds were

Table 1. Factor Levels

Level	Seeds conditions A	Moisture contents B	Types of seeds C	Friction materials D
1	1(coated)	1(10%db)	1(Ilyou838)	1(Steel with paint covering)
2	2(non-coated)	2(15%db)	2(Ilyouduoxi57)	2(Steel without paint covering)
3		3(20%db)	3(Gongyou22)	3(PVC plastic)

Table 2. Experimental Arrangements (Orthogonal Design $L_9(3^4)$) and Results

Test no.	A	B	C	D	f_d
1	1(coated)	1(10%db)	1(Ilyou838)	1(Steel with paint covering)	0.5132
2	1	2(15%db)	2(Ilyouduoxi57)	2(Steel without paint covering)	0.5551
3	1	3(20%db)	3(Gongyou22)	3(PVC plastic)	0.4006
4	2(non-coated)	1	2	3	0.3665
5	2	2	3	1	0.5334
6	2	3	1	2	0.6263
7	3(1 coated)	1	3	2	0.5232
8	3	2	1	3	0.4397
9	3	3	2	1	0.5540

Table 3. Analysis of Variance

Source of variation	Sums of squares ($\times 10^{-3}$)	Degree of freedom	Mean squares ($\times 10^{-3}$)	Variance ratio (F)	Variance ratio (F_{-ratio})
A	0.246	1	0.246	Δ (merged into error)	$F_{0.25}$ (2,2)=3.00
B	5.574	2	2.787	8.848	$F_{0.1}$ (2,2)=9.00
C	2.889	2	1.442	4.578	$F_{0.05}$ (2,2)=19.00
D	45.967	2	22.984	72.965 *	$F_{0.01}$ (2,2)=99.01
Error & A	0.630	2	0.315		
Total	55.054	8			

close to each other, which led to the moisture contents' relatively low significant effects on dynamic friction coefficients.

Seed conditions (coated or not) had little effects on dynamic friction coefficients. Much awns of rice seeds were lost when seeds are being coated accompanied by movements of kneading and stirring. At the same time, the surfaces of rice seeds were covered with a layer of seed coating formulation. Moreover, the moisture contents of coated rice seeds were low. All these factors resulted in seeds conditions' quite low effects on dynamic friction coefficients. Using coated rice seeds for factory seedling nursery has many advantages.

Through orthogonal engineering average, we calculated the dynamic friction coefficients of the three types of hybrid rice seeds tested between seeds (of different moisture contents) and certain friction materials. By means of regression analysis and regression equations (with comparatively high coefficients of correlation) between the dynamic friction coefficients f_d of the three types of hybrid rice seeds and moisture contents m_c were set up as well. The regression equation of IIyou838 on steel with paint covering is:

$$f_d=0.5254+0.0059m_c \quad (r=0.9822).$$

Factory seedling nursery using coated rice seeds renders them to dibble-drilled directly and delivered into the seedling nursery factory with high drilling precision.

The moisture contents levels tested quite matched the working conditions of rice seeds for precision drilling, hence the dynamic friction coefficients from experiments have practical values. However, non-coated rice seeds used for factory seedling nursery must be treated according to requirements of seed soaking accelerating germination. Thus, non-coated rice seeds are drilled at quite high moisture contents (>40%db). This is unfavorable to machinery drilling and may cause rice seed damaged.

We also tested other physical and mechanical properties of the coated rice seeds, as these properties can provide a basis for parameter designs and performance analysis on drilling devices based on using coated rice seeds.

Conclusions

The friction mechanism between rice seeds and different materials is quite complicated as many factors can affect it. By means of orthogonal experiments, the major factors affecting the dynamic friction coefficients of coated rice seeds and their significant levels were determined. The moisture contents tested quite matched the working conditions of rice seeds for precision drilling for seedling nursery. The dynamic friction coefficients from experiments have many practical values.

The testing instruments for collecting and analyzing the data by a new sensor system and a single-chip computer gave rise to high testing precision.

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Animal-drawn Soil Working Four-in-one Implements

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INDIA

Absract

Most of the agricultural operations in Asian countries are based on the bullock power. There are different types of bullock drawn implements for various farm operations, but the purchase of these implements at the level of small and medium farmers is difficult due to their high initial cost. Keeping this in view, an effort was made to develop a low-cost soil working implements with a common wooden frame and four different attachments indigenous plough, mould board plough, ridger and potato digger. Different components of common frame and all four attachments were designed and fabricated. The performance was evaluated in the actual field work. Various parameters like draft, shape and size of furrows, pulverization, soil inversion, field capacities and field efficiencies were recorded. The cost of the newly-developed implement was Rs.1150.00 against the total cost of independent units at Rs.2400.00 approximately required for all four activities. The performance of the newly-developed implement was equally good with two times more economy. The field capacities and field efficiencies of the indigenous plough, mould board plough, ridger and potato digger were 0.035 ha/h, 0.034 ha/h, 0.25 ha/h, 0.118 ha/h and 77.8%, 85%, 89% and 91%, respectively. Thus the newly-developed implement should contribute a great change in the existing system of soil working implements with a significant savings.

Introduction

Indian agriculture basically depends upon bullocks power as more than 82% of all the farmers hold below 2 ha farms. Keeping tractor and any other big machinery is beyond the economic capability of these farmers. They prefer to use a pair of bullocks along with small matching implements like indigenous plough and mould board plough. It has been estimated that India has about 85 millions of draft animals. Hence, the future prospect of Indian farming largely depends upon the utilization of animal power through different matching implements in an efficient manner. In the present study, an effort was made to develop an improved implement similar to tool carriers which can be used for the attachments of several types of implements for various field work like ploughing, soil inversion, ridge formation and potato digging. Though such implements are already available and offer several advantages like timeliness of farm operations, quality and precision of works, efficient utilization of animal power and allows for year-round use due to its multi-purpose utility. But due to their high initial cost and relatively higher draft requirement, these tool carriers are not popular. The present study was, therefore, undertaken with a view to developing a simple low cost multi-purpose soil-working implement suitable for a pair of bullocks.

A study by Mourya and Devadattam (1985) evaluated animal-drawn multi-purpose tool carrier involving four treatments consisting of Tropiculture, Krishirath, a set of improved implements and another set of indigenous implements as control. It was observed that the draft requirement of the first two treatments was over 200 kg making them unsuitable for medium size bullocks. The power requirement was 2.10 hp and 1.71 hp, respectively, for the first two treatments. It was also observed that there was no definite trend in the reduction in cost of operation per unit area due to high initial cost of the equipment.

Mayande, Bansal and Sangle (1985) evaluated the performance of animal-drawn four different wheeled-tool carriers. It was concluded that all four wheeled tool carriers have insignificant effect on the actual field capacity for various operations irrespective of the design differences. It was observed that bullocks used for wheeled tool carriers were capable of generating high power output.

Tajuddin and Karunanithi (1987) developed a bullock-drawn improved iron plough at the Tamil Nadu Agricultural University, Coimbatore. The improved plough was provided with a mould board as an optional attachment. This could be fitted to the plough if soil inversion is required. The components of the improved plough could easily be dismantled, assembled and transported from one place to another. The improved iron plough could cover an average area of about 0.5 ha/day. The plough could be pulled by an ordinary pair of bullocks.

Materials and Methods

As discussed earlier, the various components of soil working implements were designed from the viewpoint of their proper functioning and sufficient strength. A common wooden frame and body of the plough were designed to withstand a maximum load of 1 hp of a pair of bullocks. At the same time it has provision to accommodate various attachments like indigenous plough, M. B. plough, ridger and potato digger one by one as and when required. It was also essential for farmers to replace various attachments without any use of spanners or wrenches during the actual field use of the implements. Thus, a common wooden frame and its various attachments i.e. indigenous plough, M. B. plough, ridger and potato digger were designed and fabricated.

Design of Common Wooden Frame

The detail specifications of the common wooden frame, beam and handle are shown in **Fig. 1**. The length and thickness of the beam was 2.9 m and 0.04 m, respectively. The beam was designed to withstand tensile load of 1060 N. A *shisham* wood was selected for fabrication of the beam for which tensile and bending strengths were 17 MPa and 14 Mpa, respectively. Thus, the designed width was 0.075 m.

Six grooves were cut on the upper portion of the beam to function as a vertical clevis to facilitate the hitching with different sizes of bullocks. This also facilitates adjustment depth of working of different implements.

The common frame (handle) was designed to accommodate different attachments at its lower end, beam in the middle portion and handle grip at the top. It was also made of *shisham* wood. The height of handle was 1.025 m to suit an average hand height of Indian farmers. The length and width of common frame (handle) was 1.025 m and 0.135 m, respectively. The designed thickness of common frame was 0.09 m. A rectangular hole of 90 x 40 mm was made at a height of 380 mm to accommodate the beam as shown in **Fig.1**. Similarly, a tapered hole was also made at 40 mm above the bottom end of common frame to accommodate different attachments of soil working components.

Design of Mould Board Plough

The mould board plough attachment to the common frame was designed to function as soil turning plough with an average size of bullocks at a working speed of about 2.5 km/h. The ploughing depth was 0.125 m. Thus the designed values of different parameters were maintained as given in **Table 1**.

A complete view of M.B. Plough is shown in **Fig. 2**.

Design of Indigenous Plough

The indigenous plough was designed to function as a single type cultivator to replace an existing indigenous plough. It works in the depth range of 50 mm to 120 mm with an working width of 150 mm. The tilt angle (γ) was 25°. A similarly bevel angle (β_1) was 10° and apex angle (2α) as 10°. The length of share (L) was 175 mm. The detail specifications are given in **Table 2**.

The plough was fabricated by local blacksmith by heating and hammering method and a view of the same is shown in **Fig. 3**.

Design of Ridger

The ridger was basically designed as a double mould board plough to prepare ridges for planting of seed potato. It was also designed to use for trench formation

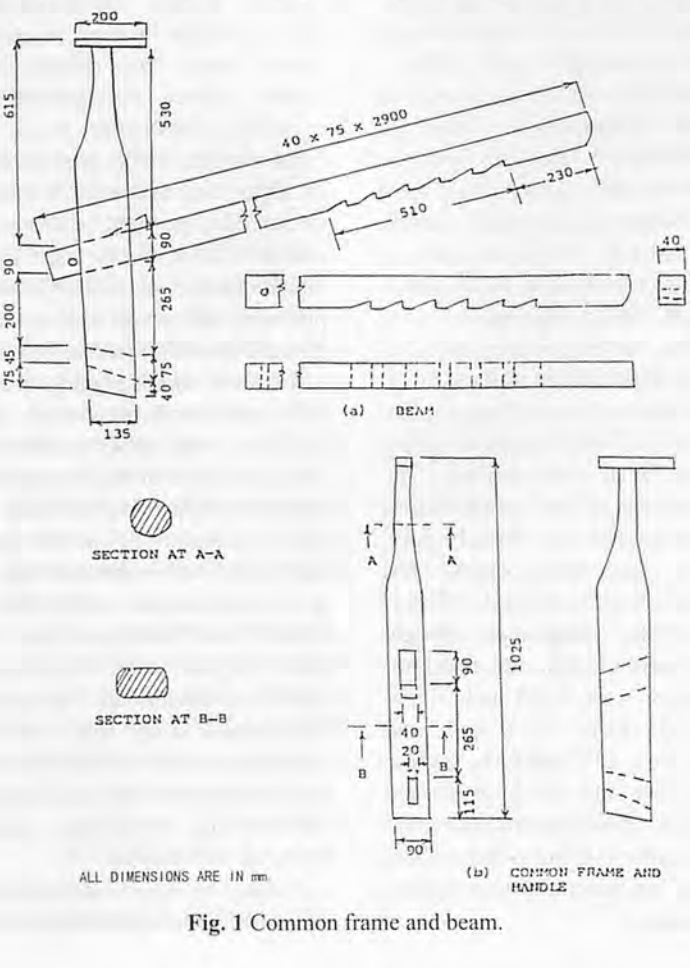

Fig. 1 Common frame and beam.

Table 1. Design details of Mould Board Plough

Item	Specifications
Name	Mould Board Plough
Power Source	A pair of bullocks
Width of cut	0.16 m
Angle of inclination	51.38°
Lift angle	30°
Blade inclination to the furrow wall in horizontal plane	42°
Minimum crumbling angle	30°
Maximum crumbling angle	95°
Back clearance angle of share	10°
Angle of taper	35°
Cutting angle	45°
Bevel angle	10°
Net weight of implement (attachment)	4 kg
Thickness of share	6 mm
Thickness of mould board	6 mm
Materials of construction i) Share	High carbon steel
ii) Mould board	Mild steel
Cost	Rs.185.00 (approx.)

Table 2. Specification details of Indigenous Plough

Item	Specifications
Name	Indigenous plough
Power Source	A pair of bullocks
Width of cut	0.165 m
Operating depth	0.125 m
Total length	0.37 m
Length of share	0.175 m
Angle between share and shoes	146°
Apex angle of share	10°
Lift angle	30°
Bevel angle of share	10°
Height	0.25 m
Net weight (attachment)	3 kg
Materials of construction	
i) Share	High carbon steel
ii) Mould board	M.S. sheet
Thickness of share	6 mm
Cost	Rs.175.00 (approx.)

in a ploughed field for planting of sugarcane sets. The earthing up work in sugarcane crop can also be performed by the ridger. It consists of three main components: share, twin mould board and "frog".

The share and mould board were connected by riveting them with the frog as shown in **Fig. 4**. The detail specifications of the ridger are given in **Table 3**.

Design of Potato Digger

The potato digger consists of a share, lifting rods, shoe and frog. The lifting rods were designed to lift the potato and to separate them from the soil. The detail specifications of potato digger are given in **Table 4**. A view of newly-developed potato digger is also shown in **Fig. 5**.

The specifications of frog were maintained identical in all the implements as shown in **Fig. 1**. These four attachments can be used one by one to a common frame as shown in **Fig. 6**.

These attachments were tested for various field operations as per their designs. The indigenous plough was tested for ploughing. The M. B. plough was tested for soil turning operation. The ridger was tested for ridge formation and trench formation work which are required very often for sowing of potato and sugarcane sets as well as earthing work in the standing crops of sugarcane. The potato digger was tested for potato digging operation.

A pre-calibrated hydraulic dynamometer was used to measure the draft. The working speed was measured by observing the distance traveled in a specified time. The area covered was also measured within a specified time to determine the field capacity and field efficiency of the various attachments. The size and shape of the furrow was measured with the help of two steel scales. Other parameters were recorded as per standard test procedures. The cost analysis was carried out to determine the actual cost of use of the newly-developed implements over the traditionally used independent implements for all four field operations.

Results and Discussion

The newly-developed implements were tested in actual field for measurement of various parameters like draft, shape and size of furrow, depth of working, soil pulverization, soil inversion, bulk density, field capacity and field efficiency.

Draft of the Implements

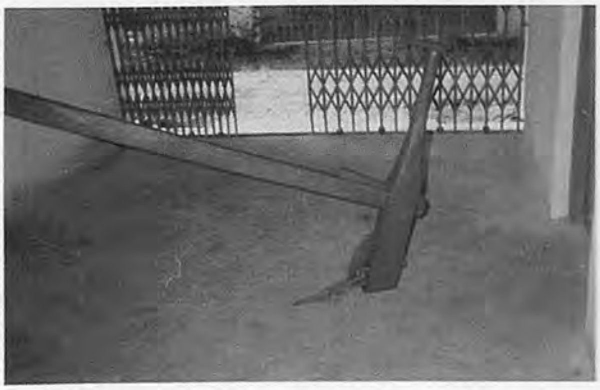

Fig. 2 Complete view of mould board plough.

Fig. 3 Complete view of indigenous plough.

Table 3. Specification Details of Ridger

Item	Specification
Name	Bullock drawn ridger
Type	Twin mould board type
Power source	A pair of bullocks
Width of cut	0.3 m.
Maximum height of wing	0.25 m.
Net weight (attachment)	4.0 kg.
Materials of construction	
Share	High Carbon steel
Mould board	M.S. sheet
Thickness of Share	6 mm
Thickness of mould board	6 mm
Cost	Rs.195.00 (approx.)

Table 4. Specification Details of Potato Digger

Item		Specifications
Name		Bullock drawn potato digger
Type		Plough type
Power source		A pair of bullocks
Theoretical width of cut		0.15 m
Actual width of operation		0.175 m
Apex angle (2 α)		10°
Length of share		0.19 m
Total height		0.30 m
No. of lifting rods		8
Sizes of lifting rods		0.2 / 0.25/ 0.30/ 0.35 m
Net weight (attachment)		4.5 kg
Materials of construction	i) Share	H.C.steel
	ii) Shoe	M.S.sheet
	iii) Lifting rods	M.S.rod
Thickness of share		6 mm
Cost		Rs.185.00

The drafts of the mould board plough, indigenous plough ridger and potato digger were measured with the help of a pre-calibrated hydraulic dynamometer. The minimum value of draft with the ridger was 332 N at the forward speed of 3.09 km/h (**Fig. 7**). This was followed by the potato digger and mould board ploughs, which were 536.12 N and 667 N, respectively. The maximum draft of the indigenous plough was 724.37 N. The lower value of the draft for the ridger was obtained from operation of the ploughed field. The higher draft of indigenous plough may be attributed to the fact that it was operated in an unploughed land and there was a tearing effect in the soil during the actual work. The mould board plough cut the soil slice smoothly due to the sharpened edge of shear and hence required comparatively lower draft.

Shape and Size of Furrow

The observations taken during the actual work indicates that a trapezoidal shape of furrow was formed with the indigenous plough. It was rectangular in the case of the M. B. plough, and triangular in the case of the ridger and potato digger. The average width of cut and depth of cut were 148 mm and 124 mm, respectively, for the indigenous plough. The mould board plough opened the furrow of 156 mm wide and 123 mm deep. The width and depth of furrow of the ridger were 300 mm and 205 mm, respectively. In the case of the potato digger the width and depth of furrow were 150 mm and 124 mm, respectively. The maximum depth of 205 mm was achieved with the ridger whereas the minimum average depth of 123 mm was achieved with the mould board plough. The indigenous plough and potato digger had almost similar depths of about 124 mm each.

The cross sectional area of the furrows made by ridger was maximum at 0.031 m^2. The minimum cross sectional area of the furrows was 0.0093 m^2 with the potato digger followed by the indigenous and mould board ploughs at 0.0107 m^2 and 0.0192 m^2, respectively.

Soil Pulverization

The soil pulverization of the indigenous and M. B. ploughs was measured in terms of mean mass diameter (MMD) and recorded at 50.57 mm for the indigenous plough and 54.3 mm for M. B. plough which were well within the acceptable range.

Soil Inversion

The soil inversion was measured only for the M. B. plough which was 83.92% showing its acceptance for soil inversion work.

Field Capacity and Field Efficiency

Fig. 4 Wooden frame with ridger.

Fig. 5 Wooden frame with potato digger.

Fig. 6 Common wooden frame with all four attachments.

The effective field capacity of the indigenous plough was 0.035 ha/h and that for the M.B.Plough was 0.034 ha/h. The ridger had maximum field capacity of 0.138 ha/h for the potato cultivation and 0.25 ha/h for sugarcane. The field capacity of the former was 0.118 ha/h (**Fig. 8**).

The maximum field efficiency of the potato digger as 91% whereas that of the indigenous plough was only 77.8%. The field efficiencies of mould board plough and ridger were 85% and 89%, respectively.

Unit Cost of Operation

The cost of use of the newly-developed implements were calculated by considering all four attachment as integrated units in performing ploughing, soil turning ridging and potato digging operations. The total working hours was 880 per year compared the use of bullocks 1,200 hours per year.

The cost analysis of existing implements was considering all units as one set. The cost of implements was also considered as the cost of one set to perform various operations. The study shows that the newly-developed implements could save Rs.0.57 or Rs.501.60 per year.

Summary

i) The draft requirements of indigenous plough, mould board plough, ridger and potato digger were found to be 724.37N, 667 N, 332 N and 536.12 N, respectively. These values were well within the draftability range of a pair of bullocks.
ii) Soil pulverization was measured in terms of mean mass diameter. It was 54.3 mm in the case of the mould board plough and 50.57 mm for the indigenous plough.
iii) The soil inversion of the mould board plough was 83.92%, which is quite acceptable.
iv) The field capacity of the indigenous plough, mould board plough, ridger and potato digger were 0.035 ha/h, 0.034 ha/h, 0.25 ha/h and 0.118 ha/h, respectively with the field efficiencies of 77.8%, 85%, 89% and 91%, respectively.
v) The newly-developed implements made an overall savings of about Rs.0.57 per hour or about Rs.501.60 per year.
vi) The initial price of the four implements was Rs.1,200.00 compared Rs.2,400.00 for other existing units.

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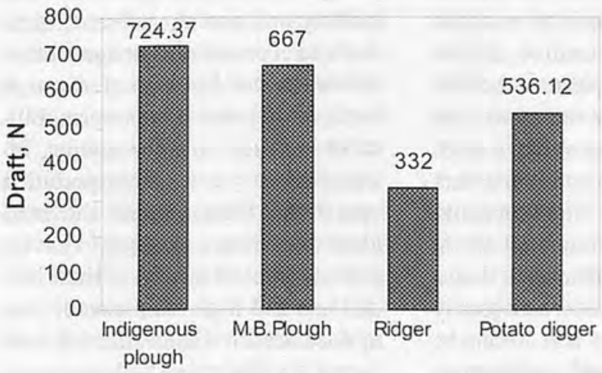

Fig. 7 Draft of different attachments.

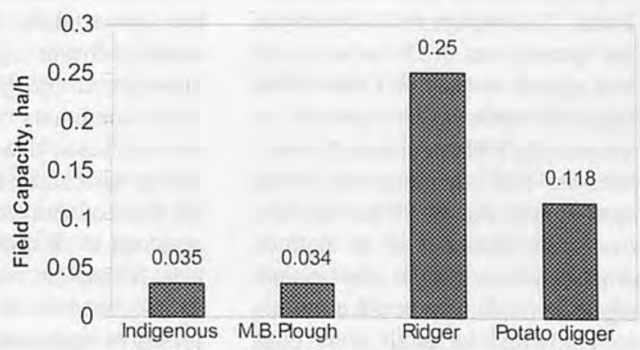

Fig. 8 Field capacity of different implements.

Design and Development of Bullock Drawn Traction Sprayer

by

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Abstract

A bullock-drawn traction sprayer was designed considering agronomical, functional requirements and physical, economical considerations. The performance of the sprayer was evaluated for different parameters in laboratory and field conditions at pressure of 3.5 kg/cm^2. The average boom discharge was observed at 2.47 lit/min and 2.53 lit/min in laboratory and field conditions, respectively. The spray distribution pattern was uniform for all the nozzles at 400 mm height. The spray pattern becomes wider for the central nozzle as compared to end nozzles at 400 mm height. The average horse power required to operate the machine was 0.486 hp which was well within the pulling capacity of the bullocks. The average field capacity of the sprayer was 0.704 ha/hr, which was almost seven times that of the knapsack sprayer. The sprayer required only 1.44 man-hour to cover 1 ha area. The operating cost of the sprayer was Rs. 40.86 per ha. The overall performance of the bullock drawn traction sprayer was promising. It is simple, inexpensive and can be fabricated in small workshops with locally available materials.

Introduction

India is a developing country based on agricultural industries. Among the various production constraints, one of the important constraints is pest problem occurring at various growth stages of the crops, which is responsible for achieving low yields. Pest control, race against time and timeliness of applying the chemicals is the most important factor. The chemical control method of plant protection differs from physical, cultural, biological and genetic methods in its universal applicability and effectiveness with relatively low expenditure of labour and material. Now a day many different kinds of spraying and dusting machines are available and new developments are always taking place to meet the requirement of agriculture in the changing cropping pattern and climatic conditions for the control of insects, pests, diseases and weeds. Indian agriculture is so diverse that all types of sprayers from manually operated to aircraft mounted are in use. It may be emphasized that a simple machine is not necessarily primitive equipment and it can be perfected in design and performance to yield desired results. The modernization of spraying equipment has gone hand in hand with the development of new agrochemicals and improved application techniques. The proper selection of pesticide and application of the correct dose at the proper time are not only attributes of good performance in pest control but in order to obtain maximum returns from their use, it is necessary to select the most efficient equipment for securing a uniform deposit on the target without any wastage of material in least time and with minimum labour and fatigue (Reddy and Joshi, 1976). Hence selection and use of equipment is of utmost importance and deserves more emphasis while considering pesticide applications.

In agriculture, the contribution of draught animals is significant and leading one and therefore, utilization and economical management of animal power by way of research work is of prime importance. Bullocks are used only for sowing, interculturing and transportation operations. Hence, small and marginal farmers are required to have a pair of bullocks instead of their limited use and high maintenance cost in slack season. Hence, there is need to increase the use of bullocks in agriculture. Animal drawn sprayer is technically intermediate between the hand operated knapsack sprayer and completely mechanized sprayer and suited to a wide range of conditions. Keeping all these facts in mind a bullock drawn traction sprayer was designed and its performance under laboratory and field conditions was evaluated to avoid the problems involved in spraying operation and to provide a simple, economical and efficient spraying equipment suitable for farming systems of small and marginal farmers of developing countries.

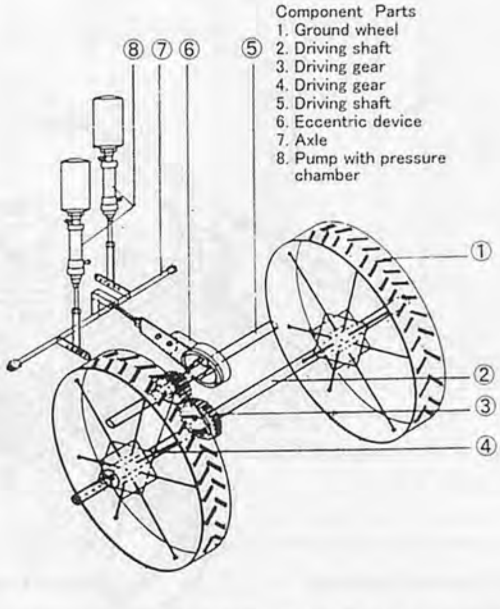


Fig. 1 Power transmission system of bulllock drawn traction sprayer.

Design Considerations

Bullock drawn traction sprayer was designed considering agronomical, functional requirements and physical, economical considerations. Agronomical requirement includes row spacing and height of crop. Functional requirement includes wheel track, draft, pulling capacity of bullocks, pressure in nozzles, number of nozzles and different soil conditions with minimum wheel slippage. Physical and economical considerations include simplicity in design, durability, low cost, use of locally available materials and low operation and maintenance cost.

Power Transmission Unit

Ground wheel of 600 mm diameter having rim width of 100 mm was designed and fabricated from MS flat to suit the height of groundnut crop so that spraying operation could be done easily without damaging the plants. MS bar lugs (10 × 10 mm) were welded at an angle of 30^0 on the periphery of the wheel to avoid slippage. A set of two spur gears (48-and 24-teeth) with a gear ratio of 1:2 was selected to maintain the number of strokes required to develop the pressure of 3 to 4 kg/cm^2 for operating five nozzles at a time at a particular bullock speed. Eccentric device with 50-mm stroke length was used to transmit the rotary motion of ground wheel to oscillatory motion of the link which actuates both pumps (**Fig. 1**).

Component Details of Sprayer

A cylindrical tank of 60 liters capacity made of corrosion resistant synthetic plastic material with round corners was used because it is cheap, durable and can be used for various application rates. Two single-acting reciprocating pumps with a 50-mm cylinder diameter and 75-mm stroke length were mounted on the frame of the machine. A pressure gauge (0 – 10 kg/cm^2) was attached between the pump and nozzle to measure the fluid pressure. A flexible PVC hose pipe of 7 mm inner diameter was used to carry a high pressure fluid. Five hollow-cone nozzles were selected for spreading the varieties of crops since they produce finer droplets, spray penetrates better into the plant foliage, suitable for low volume application. The spray angle is narrow to medium. The frame was made of strong and sturdy MS channels of 75 × 35 × 5 mm to support and hold different components. A provision was made to vary the angle of beam by changing the position of attachment unit.(**FIg. 2**)

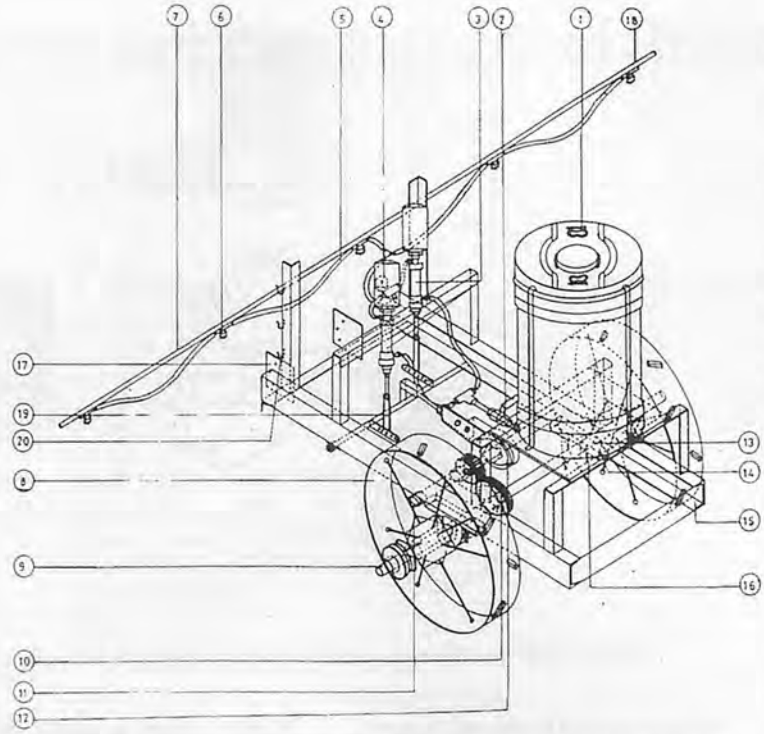
Testing of Bullock-Drawn Traction Sprayer

The performance of the machine was evaluated in both laboratory and field as per BIS codes (IS:8548-1977 and IS:10134-1994). The height of the boom and position of nozzles was adjusted so that the crop is not damaged by the boom and the spray covers the plant completely and uniformly. The pressure was maintained by continuous operation of the two pumps.

Laboratory Testing

The sprayer was elevated somewhat in order to make the ground wheel free to rotate. The power was supplied by an electric motor through a V-belt and pulley arrangement to drive the ground wheel at the speed of the bullocks. Red colour clean water was used as a spray fluid and dye, respectively.

The spray discharge was collect-



SR. NO.	COMPONENT	MATERIAL
20	HOOK	M.S. ROD
19	AXLE	BRIGHT BAR
18	CLAMP	G.I. FLAT
17	HITCHING PLATE	M.S. FLAT
16	PLATE FORM	WOOD
15	FRAME	M.S. CHANNEL
14	PEDESTAL	CAST IRON
13	BEARING	STANDARD
12	ECCENTRIC DEVICE	CAST FRON
11	DRIVEN SHAFT	BRIGHT BAR
10	GEAR	STANDARD
9	DRIVING SHAFT	BRIGHT BAR
8	GROUND WHEEL	M.S. FLAT
7	BOOM	G.I. PIPE
6	NOZZLE	BRASS
5	HOSE PIPE	FLEXIBLE PVC
4	PRESSURE GAUGE	STANDARD
3	PUMP WITH PRESSURE CHAMBER	BRASS
2	SHUT OFF VALVE	STANDARD
1	CHEMICAL TANK	SYNTHETIC PLASTIC

Fig. 2 Bulllock drawn traction sprayer.

ed in measuring the cylinder for a minute duration at 3.5 kg/cm^2. The process was replicated five times and the average value of discharge was taken as representative value. The spray distribution pattern and swath width of the nozzle were calculated by using corrugated sheet of galvanized iron inclined at 20^0 with the horizontal. The spray liquid collected at the lower end of corrugated sheet was measured with the use of a graduated cylinder immediately after the test run. The width of each individual corrugation was 7 cm. For measurement of droplet density and droplet size, an Olympus Series BH System microscope and particle size micro-meter and analyser were used. White glossy papers (30 × 30 cm) were used to collect the droplets. Red colour was added to the liquid for easy identification of droplets on glossy papers placed at a distance of 40 cm from respective nozzles.

Field Testing

Field testing of the sprayer was conducted at the *Krishi Gadh* farm of Gujarat Agricultural University, Junagadh. Five hallow cone nozzles were placed at 90 cm spacing on the boom depending upon the crop row spacing. Groundnut crop, variety GG-11, spreading type was selected for target. The soil moisture content was determined by standard oven dry method collecting five samples randomly from the test plot. The spring drawbar dynamometer (0 – 200 kg) was attached between the yoke and beam. The inclination of the beam with horizontal was determined by measuring vertical and horizontal distances between two points by the equation 1:

$$\theta = \tan^{-1}[(a-b)/c] \quad \text{..............} (1)$$

The Discharge of each nozzle at 3.5 kg/cm^2 pressure was collected in the measuring cylinder. Time losses in turning, cleaning, adjustment and refilling of liquid were recorded. Various parameters such as power requirement, field capacity and field efficiency were calculated.

Results and Discussion

The performance of the sprayer was evaluated in terms of discharge, spray distribution pattern and droplet size distribution. The speed of ground wheel of the sprayer was kept at 25 rpm (bullock speed) during the laboratory testing whereas it was operated at 2.9 km/hr during the field testing.

Discharge Rate

The results indicate that the average discharge of individual nozzle varied from 477 to 510 ml/min with average boom discharge of 2.47 lit/min (**Table 1**). **Figure 3** shows that the maximum discharge was N_3 (510 ml/min) for nozzle. The discharge for nozzles N_1 and N_5 was 477 ml/min and 480 ml/min, respectively. No significant difference was observed in discharge rate among nozzles N_2, N_3 and N_4. However, minor difference was observed in nozzles N_3, N_1 and N_5, probably due to slight pressure drop at the end nozzles. The coefficient of variation of nozzle discharge varied from 3.02 to 3.85% with average coefficient of variation

Table 1. Discharge Rate of Individual Nozzles at Laboratory and Field Conditions at 3.5 kg/cm^2

Test No.	Discharge rate (ml/min.)					Ave* (ml/min.)	C.V (%)	Total* (l/min.)
	N_1	N_2	N_3	N_4	N_5			
Laboratory Testing								
1	465	490	510	495	480	488	3.08	2.44
2	475	520	495	505	490	497	3.02	2.48
3	480	505	520	510	475	498	3.51	2.49
4	495	505	515	490	470	495	3.06	2.47
5	470	495	510	525	485	497	3.85	2.48
Avg.	477	503	510	505	480		3.30	2.47
Field Testing								
1	480	505	535	520	495	507	3.77	2.54
2	495	525	540	490	515	513	3.63	2.56
3	515	545	560	535	510	533	3.48	2.66
4	465	480	495	475	480	479	2.02	2.40
5	470	495	500	520	485	494	3.35	2.47
Avg.	485	510	526	508	497		3.25	2.53

*Average discharge (ml/min.)

**Total discharge of boom (l/min.)

3.30%.

During field-testing the average discharge of individual nozzle varied from 485 to 520 ml/min with boom discharge of 2.53 lit/min (**Fig. 3**). The difference in discharge rate during laboratory testing and field-testing was probably due to variation in bullock speed in the field condition. The coefficient of variation of nozzle discharge varied from 2.02 to 3.77% with average value of 3.25% (**Table 1**). The average time and volume of spray fluid required to cover one ha were 1.4 hr and 127.8 liters, respectively.

Spray Distribution Pattern

The spray distribution pattern of the individual nozzles was obtained at different nozzle height of 100, 200, 300 and 400 mm from center of the test set up. It was observed that the swath width increased with an increase in height of the nozzle but spray angle decreased. Maximum swath width and spray angle were observed in nozzle N_3 and minimum for N_1 and N_5 (**Table 2**). The spray distribution pattern was uniform for all the nozzles at 400 mm height. The spray pattern obtained was wider at 400 mm height for central nozzle as compared to the end nozzles (**Fig. 4**).

Droplet Size Distribution

A greater number of droplets was found in the range of 50 to 300 micrometers for all the nozzles. The VMD of droplets varied from 250 to 260 microns for different nozzles. The VMD of droplets in the range of 120 to 300 microns were found effective (Pandya, 1994). The minimum number of droplets per square cm was 61 for nozzle N_1 and 62 for N_5 whereas the maximum for nozzle N_3 was 83 at 3.5 kg/cm^2 of pressure (**Table 3**).

Power Requirement

The average pull required to operate the sprayer was 48 kg at 19.29^0 from horizontal, whereas the average draft of 45.30 kg was recorded at an average forward speed of 2.9 km/hr. The average power required to operate the sprayer was be 0.486 hp. An average pair of bullocks can produce about 0.8 to 1.5 hp (Maurya, 1985). Hence, a pair of bullocks can easily operate the traction sprayer.

The man hours required for spraying one ha area with the developed sprayer varied from 1.3 to 1.6 with an average of 1.44, whereas the knapsack sprayer requires 14 man-hours/ha (Awadhwal, 1993). The cost of operation per hectare was Rs. 40.86, which was very low due to its high field capacity (0.704 ha/hr).

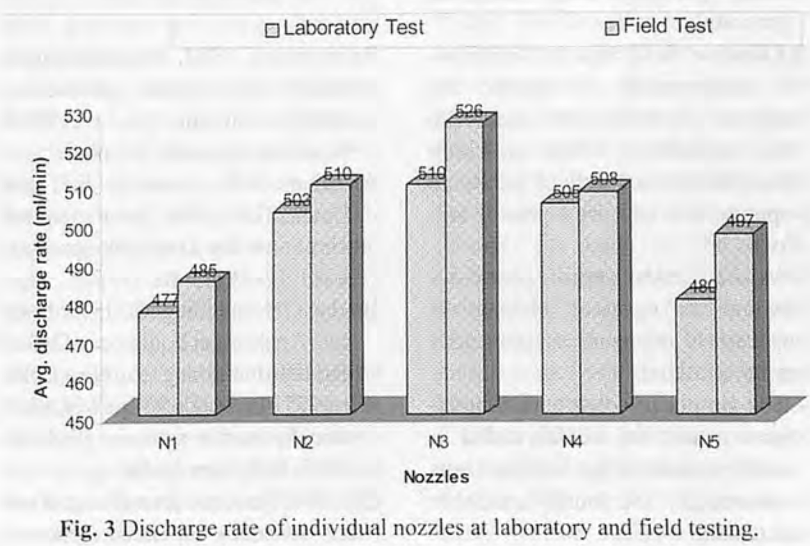


Fig. 3 Discharge rate of individual nozzles at laboratory and field testing.

Table 2. Swath Width and Spray Angle of Nozzles at Different Heights at 3.5 Kg/cm^2

Height of nozzle (mm)	N_1		N_2		N_3		N_4		N_5	
	Swath width (mm)	Spray angle (deg.)	Swath width (mm)	Spray angle (deg.)	Swath width (mm)	Spray angle (deg.)	Swath width (mm)	Spray angle (deg.)	Swath width (mm)	Spray angle (deg.)
100	170	80.47	180	83.46	190	86.23	175	82.49	175	82.49
200	230	59.18	260	65.65	280	69.89	270	67.83	250	64.13
300	290	51.45	325	56.77	390	63.08	340	58.59	315	54.86
400	370	49.24	390	51.97	450	58.29	430	56.46	380	50.36

Efficiency of the Sprayer

Time lost in turning, cleaning and adjustment and refilling varied from 3-4, 1-4 and 2-3 minutes, respectively. The time lost in turning was greater because as the area increased with respect to width, turning loss also increased. The theoretical field capacity at 100% time utilization was 1.305 ha/hr whereas the effective field capacity at productive time was 0.704 ha/hr. The field efficiency of the developed sprayer varied from 46.74 to 59.00% with an average of 53.94%. The knapsack sprayer covers about 0.1 ha/hr (Ahuja, 1979). This shows that the coverage of the developed traction sprayer was much higher about seven times than that of the knapsack sprayer.

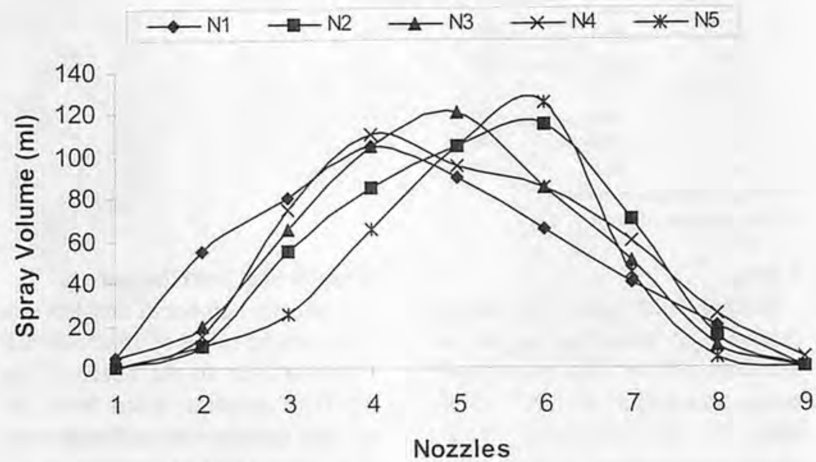


Fig. 4 Spray distribution pattern of individual nozzles at 40 mm boom height.

Table 3. Droplet Size Distribution of Nozzles at 3.5 Kg/cm^2

Nozzle	SMD (microns)	VAD (microns)	NMD (microns)	VMD (microns)	Uniformity Coefficient	No. of droplets per sq. cm
N_1	228.5	178.6	103	255	2.47	61
N_2	225.4	174.6	94	256	2.72	72
N_3	224.6	172.3	90	250	2.77	83
N_4	233.4	182.6	98	260	2.65	64
N_5	234.4	190.4	118	251	2.13	62

Conclusions

1. Uniform spray distribution pattern and maximum swath width was observed at nozzle height of 400 mm which is best suited for small growing crops such as groundnut.
2. Effective field capacity and power requirement to operate the sprayer was 0.704 ha/hr and 0.486 hp, respectively which is within the safe limit of bullock power to operate it at ease by a pair of bullocks.
3. As the sprayer applies pesticides behind the operator, chances of operator's exposure to pesticides are minimized.
4. It is simple in construction, inexpensive and can be fabricated in small workshop by local artisans with readily and locally available materials.

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CIRAD Stripper for Standing Cereal Crops: a Review of the Results

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Summary

In the 1980s, cereal farmers working in small to medium-sized plots had no access to suitable equipment for harvesting their crops. The CIRAD grain stripper was specially designed to meet these needs in developing countries. Several machines were built on the basis of a novel threshing concept and then successfully tested in Africa and Asia. This paper reviews the results obtained.

Introduction

Rice is an essential staple food crop in tropical countries (in 1989-91 period, about 150 million ha cropped with rice (FAO, 1999)). Some tillage operations such as preliminary cultivation can be mechanized with a wide range of equipment. However, rice harvesting, which is a long and difficult operation (carried out in muddy fields), is generally done manually. This often leads to substantial crop losses due to bird attacks, crop lodging, overhandling of sheaves, natural stripping due to delayed harvesting and long occupation of rice paddies which hinders planting of subsequent crops.

CIRAD-AMIS (Centre de Coopération Internationale en Recherche Agronomique pour le Développement-Département d'Amélioration des Méthodes pour l'Innovation Scientifique) thus decided to design and develop a new grain stripper.

State-of-the-art and Performance Specifications of the Cirad Grain Stripper

Mechanical Rice Harvesting in the Early 1980s

Machines are available that partially mechanize rice harvesting operations: mowing, windrowing, bunching and threshing, but considerable labour is still required to handle the sheaves, and some technical problems have not yet been solved (equipment reliability, high costs, binding problems, twine availability, etc.). Stationary threshers are used, but only for a very minor portion of crop harvests worldwide.

Combine harvesters, on the other hand, are very expensive complex machines for direct grain harvesting. Harvesters manufactured in the North are not suitable for harvesting crops in small plots, and Japanese harvesters are not sturdy (Aubin and Dagallier, 1997).

Performance Specifications of the CEEMAT-CIRAD Grain Stripper

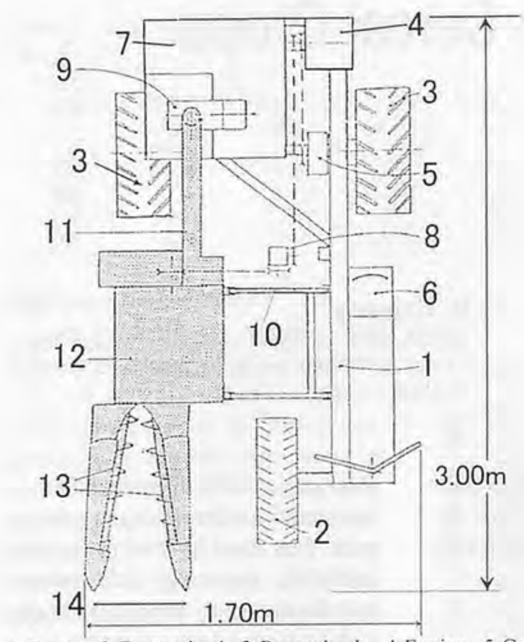
The grain stripper specifications drawn up by agronomists working in tropical crop research centres were confirmed in a market study (Marouzé, 1983). They include:
- potential for harvesting in a single pass, thus quickly leaving the plot available, requiring little labour, and the ability to harvest cut stalks with low grain loss;
- sturdy equipment that can be run and maintained by relatively unskilled operators;
- a compact machine designed for efficient harvesting in small plots like those found throughout developing countries, requiring no special modifications in the layout of rice paddy fields;
- potential for harvesting one hectare of crops a day;
- a harvester with low power requirements, capable of being driven by monocylinder engines that are common throughout these regions.

Stripper for Standing Cereal Crops: Previous Strategies

The direct cereal harvest concept is very ancient. For instance, the Gauls used a "épiéseuse" for wheat (Buchele, 1978), which had a horizontal comb that was thrust through the wheat crops. The stalks slipped through the teeth of the comb, while the larger grain heads were stripped off as the comb advanced. The harvested grain heads were then manually raked into a hopper behind the comb.

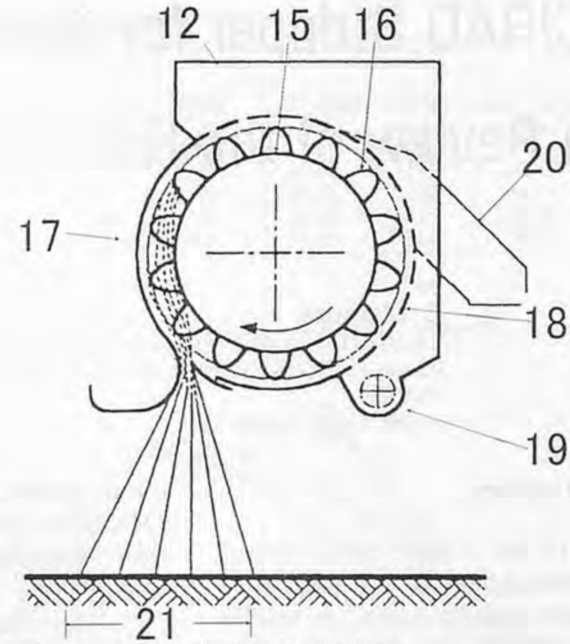
Other studies have been carried out worldwide (Marouzé 1988):

* The Poynter 403 harvester is based on the ancient header har-



1-Frame 2-Front wheel 3-Rear wheels 4-Engine 5-Gearbox 6-Seat 7-Bagging platform 8-Angle transmission 9-Bagging unit 10-Variable parallelogram 11-Elevator 12-Threshing box 13-Gathering fingers 14-Adjustable working width: 0.45-0.60m

Fig. 1 Top view of the CIRAD grain stripper.



12-Threshing box 15-Thresher 16-Wire loops 17-Unperforated concave 18-Removable perforated concave grid 19-Conveyor auger 20-Straw outlet 21-Working width: 0.45-0.60 m

Fig. 2 Section of the threshing chamber.

vester concept, but the grain heads are threshed as they are pushed by the blades of a horizontal rotor installed behind the comb;

* The International Rice Research Institute (IRRI) stripper (IRRI 1972-1975) has a flexible band equipped with two cylinders fitted with wire loops—the tops of the grain stalks are forced towards this band by a reel and the grain is carried to the back, where it is collected and stored;

* The Californian stripper (Burkhardt, 1975) has a cylinder fitted with wire loops that advance through the cereal crop and the grain heads are guided towards it by several different mechanisms;

* The G. Renaud stripper has a rotor fitted with brushes that push the grain heads against a flexible plate, thus separating the kernels from the stalks.

All of these machines have a transversal thresher, i.e., the axis is perpendicular to the direction of machine movement. This makes it difficult to harvest laid crop and keep the grain from falling on the ground.

Design of the Cirad Grain Stripper

Grain Stripper Design Concept

Standard cereal harvesting strategies were ignored when designing this stripper. CIRAD designed a grain harvester based on an original approach, i.e., stripping grain from standing crops with a longitudinal thresher. Leaving the grain stalks standing helped reduce machine size by avoiding the need for straw transfer components. This design, as compared to previous models tested on stripping standing crops, is unique because the thresher is oriented parallel to the direction of machine movement. The advantage is that the grain thresher is installed at the front of the machine. Threshing is carried out in an enclosed chamber to avoid grain loss and laid crop is collected.

Description of Stripper (Figs. 1 and 2, R02 model)

The stripper is composed of a harvesting unit installed on a self-propelled carrier.

In the harvesting unit, the guide fingers at the front of the threshing box determine the width of the strip to be harvested, collect any laid crop, and guide the grain heads into the threshing chamber. The upper parts of the stalks are forced onto a cylinder fitted with wire loops inside a cylindrical housing. The grain stripped from the stalks passes through a concave and is then carried by a conveyor auger to the back where an elevator takes it for bagging. Straw particles torn from the stalks and leaves are also carried back and ejected from the threshing unit.

The carrier unit is driven by an internal combustion engine with a mechanical transmission. It has two rear drive wheels and one steerable front wheel. This unit is equipped with a bagging unit and a driver's seat. The low-pressure back tyres can be replaced by cage wheels for harvesting crops on wet ground. The threshing unit is hitched to the carrier unit by a variable parallelogram linkage and the threshing height is manually adjusted to the crop height with a hydraulic jack.

Threshing Box in Different Models

In the R00 feasibility model (**Fig. 3a**), the thresher is partly surrounded by concaves. The right concave forces the stalks against the thresher and covers the top parts of the stalks forced into the threshing chamber, while the lower concave keeps the stalks from being drawn into the conveyor auger. After passing over the concaves, the grain falls into the conveyor auger which carries it to the rear elevator. In all of the different models, grain, straw and leaves stripped from the stalks are spiralled around the thresher towards the back and then ejected.

In the R01 prototype (**Fig. 3b**), the thresher is completely surrounded by perforated concaves. Two conveyor augers carry the grain to a rear-mounted elevator.

In the R02 and R03 prototypes (**Fig. 3c**), the first concave that forces the stalks onto the thresher is replaced by an unperforated sheet metal and there is no right conveyor auger. The grain drops into the conveyor auger installed at the bottom of the threshing box. It is transferred with a scraper conveyor.

In the R04 model (**Fig. 3d**), the concave installed around the cylinder fitted with wire loops is small (the length and diameter of the cylinder), so the grain is also separated from the straw stripped from the stalks in a second separator unit. The lower part of this unit is surrounded by a perforated concave grid, with the upper part enclosed by a straw guiding cap which moves axially. The stalks are ejected before the separator. After pass-

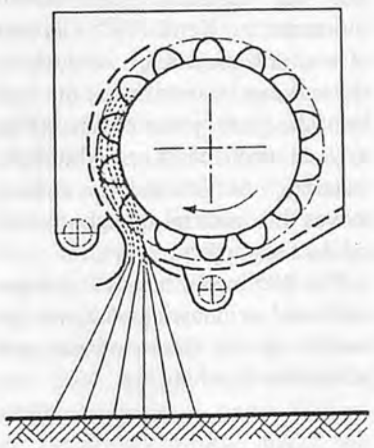


Fig. 3.a : R00 model

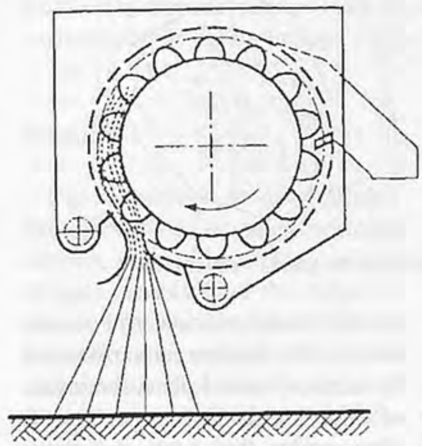


Fig. 3.b : R01 model

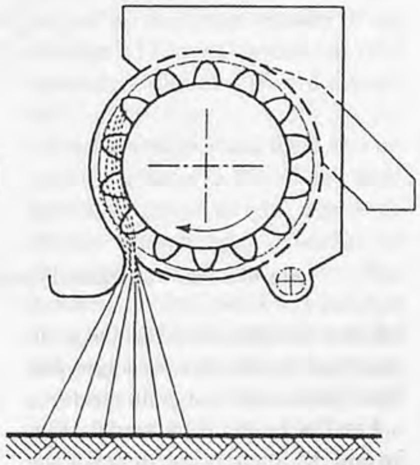


Fig. 3.c : R02 and R03 model

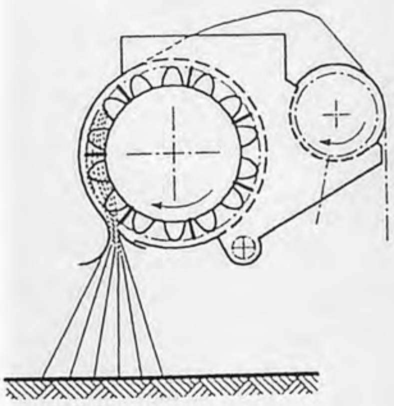


Fig. 3.d : R04 model

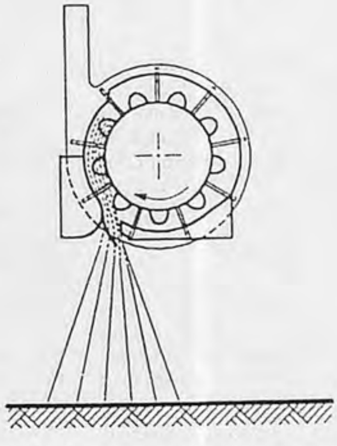


Fig. 3.e : R05 model

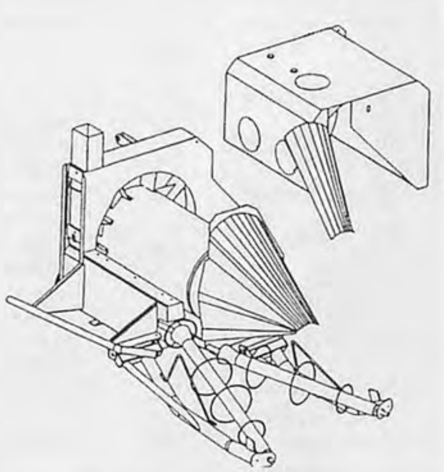


Fig. 3.f : R05 model, perspective

Fig. 3 Threshing boxes in the different models.

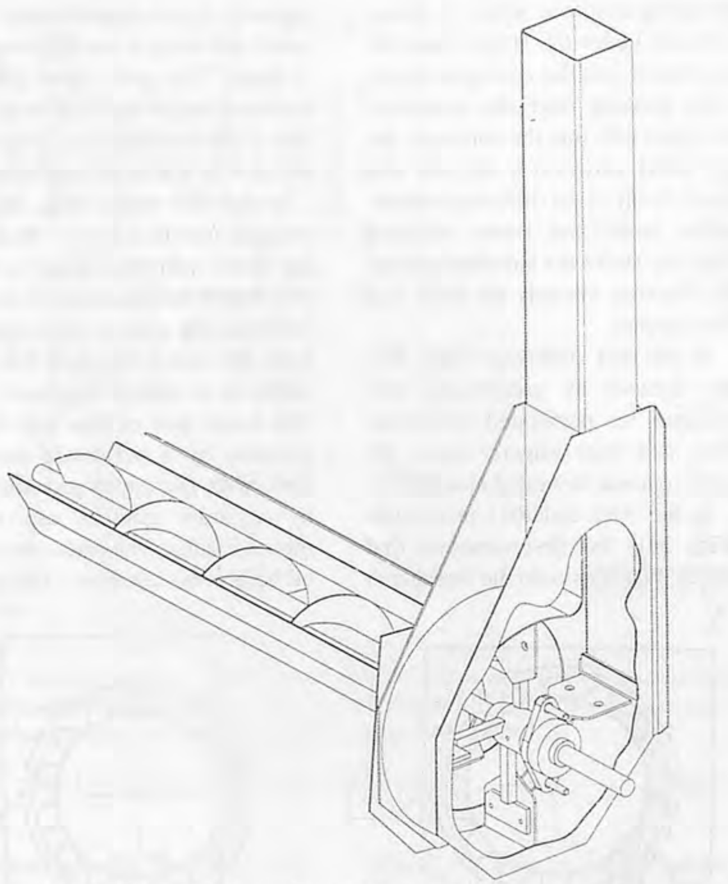


Fig. 4. Winnowing channel installed at the grain impeller outlet.

ing over the two concaves, the grain is carried by a conveyor auger and then transferred by a grain ejector.

Finally, in the R05 model (**Fig. 3e and 3f**), there is no conveyor auger, perforated concave grid or separator. The thresher is surrounded by an unperforated plate, the inside of this plate is fitted with helical plate guides that carry the straw particles and grain. At the end of the thresher, radial blades launch the grain and straw particles through a vertical duct. A separator and grain cleaning unit are fitted on the frame of the stripper.

Grain Cleaning and Transfer Units

There is no grain cleaning unit in the first three models and the grain is transferred by one or more conveyor augers and a scraper conveyor.

The R04 model has a separator fitted on the thresher box. It eliminates long material stripped from the grain stalks (straw, leaves and grass). The grain is moved by a conveyor auger and a grain ejector that was designed, implemented and tested by Kerdi (1988) as part of a thesis project. A winnowing channel can be installed at the outlet of the grain ejector channel (**Fig. 4**) to eliminate chaff and other light material. An ascending airflow moves this material though a vertical duct towards a blower.

The R05 model has both a separator and winnowing channel installed on the frame of the unit behind the threshing box.

Table 1. Performance Results of The Different Grain Strippers Tested for Harvesting Rice

Model	Separation device	Winnowing device	Grain transport device	Bagging device	Test location	Instantaneous discharge rate kg/h	Movement speed m/s	Impurities in grain %	Total grain los %
R0O	Thresher	No	Conveyor screw + elevator	Hopper	Camargue France 82	910	1	4.5	4.4
R01	Thresher	No	Conveyor screw + elevator	Bag	Camargue France 83	1000	0.92	4	1.5
R01	Thresher	No	Conveyor screw + elevator	Bag	Saint Louis Sénégal		1.1		2
RO2	Thresher	No	Conveyor screw + elevator	Bags	Yagoua Cameroun	900	1	5 to 7	
R03	Thresher	No	2 conveyors screw	Bags	Camargue France 86	1260	1.27	3 to 7	1.6
R03	Thresher	No	2 conveyors screw	Bags	San Pedro Ivory Cost	900	1	10	3
R04	Thresher + separator	Yes	Impeller	Hopper	Bouaké Ivory Cost	650	1.1	2.1	1.4
R04 bis	Thresher + separator	Yes	Impeller	Hopper	Kasetsart University	1280	1	1.4	3
		No	Impeller	Hopper	Campus Tailand	1200	1	10.9	2
R05	Thresher	Separator + Winnowing	Impeller	Hopper	Camargue France				

Fig. 5 Cirad stripper, Rth model with winnowing device in Thailand.

Carrier Units

The threshing box of the R00 feasibility model has a steerable front wheel, with the back of the box mounted on a two-wheeled tractor. The driver walks beside the machine to guide it. There is only a grain hopper installed on the frame. On subsequent models, the driver has a special seat (**Fig. 1**). The carrier unit was reinforced over the course of the project, i.e. installation of a diesel engine, larger diameter cage wheels, hydraulic lift, reinforced gearbox, tipper hopper, etc. Finally, on the R05 model, the threshing box is cantilevered at the front of a tracked vehicle with a variable parallelogram linkage.

Results

The feasibility model revealed the efficiency of the grain stripping concept with respect to all of the stripper models from the outset of the trials: $\leq 0.1\%$ of grain left on the stalks after stripping. The concept was also found to be efficient for picking up laid crop, especially the R03 model which is fitted with two long guide fingers that efficiently lift and guide the grain stalks to be stripped.

By stripping a standing crop, wheat and paddy can be threshed at a two- to threefold lower power loading rate than with combine harvesters. The stripper is equipped with a 6 HP engine, so stripping can be performed at more than 4 km/h with yields of 1000 kg/h of paddy or 1800 kg/h of wheat. In this grain stripper, contrary to standard grain stripping units where most of the power is utilized in roller-compression and grain stalk chaffing, most of the power is allocated to the main function of the machine, i.e., grain stripping. This power saving could also be explained by the linear velocity of the thresher (12 m/s), which is 30% lower than that of standard threshers.

On the first models, there was an impurity rate of 3-7% of the total harvested grain weight. Fieldside manual winnowing is essential for obtaining marketable paddy. The thresher rotation speed was boosted to enhance the versatility of the stripping unit, thus improving crop stripping. Moreover, on the R01 and R02 models, around 1% of the harvested grain was found to be

Fig. 6a Cirad stripper, Rth model without winnowing device in Thailand (front view).

Fig. 6b Cirad stripper, Rth model without winnowing device in Thailand (back view).

ejected behind the machine with straw particles stripped from the grain stalks. This problem was overcome by lengthening the pathway of the straw particles around the thresher by installing a separator; this reduced the quantity of grain ejected with straw and reduced the quantity of straw particles mixed with the harvested grain because the long material (straw, leaves and grass) are eliminated. The winnowing channel installed at the grain ejector outlet eliminates light material (chaff, empty kernels) with the grain. With these two improvements, it is possible to obtain a marketable product with 2% of impurity content.

The grain ejector can transfer grain mixed with straw and grass, which is a substantial asset when working under very harsh field conditions. Bagging grain at the ejector outlet—tested with the R03 model, can stall grain movement if the bagging operator does not carefully monitor these operations. If the bags are not replaced at the right time (e.g., when full), the ducts (even that of the grain ejector) can get clogged. The machine then has to be stopped and cleared. A storage hopper was installed on the R04 model and subsequent models as an efficient solution to this problem. The added weight of the transported grain is offset by the fact that the operator does not actually ride on the machine and by the operational reliability.

With this grain stripper, a single operator can harvest a hectare of cereal crops in 6-8 h, i.e., in one workday. The hopper is tipped onto a tarpaulin where the grains can be left to dry before bagging. Otherwise the grains can be bagged directly by equipping the hopper with a bagging spout attachment. The farmer can thus deal with both grain harvesting and bagging.

Conclusion

The CIRAD has developed a stripper for standing cereal crops that makes it possible to harvest rice under highly satisfactory conditions in terms of threshing efficiency, threshing power loading rate and threshing speed. Simplified devices were also developed for grain cleaning and transport, and they can also be implemented for other uses. Carrier units adapted for operation in rice-field conditions have also been developed. Unfortunately, this innovation has not yet been adopted in any Southern or Northern countries despite the promising results of studies carried out jointly with CEMAGREF (Martin, 1988) on implementing this harvesting concept for a wide range of machines in developed countries.

Using a longitudinal threshing unit (axis parallel to the direction of movement) reduces the width of the threshing swath and prompts the operator to thresh at high speed to obtain a satisfactory working capacity. This is not always suitable considering the reduced size of many rice field plots in developing countries. Over the course of the study, our focus on developing a versatile machine resembling a small-scale combine harvester was not always compatible with this choice.

An analysis of the design procedure (Marouzé, 1996) highlighted that it is hard to introduce a highly innovative new concept in developing countries and that deviations often occur as the design project progresses. The chances of succeeding in such projects could be enhanced by structuring and formalizing the design process. Rice harvesting equipment supplies are much more substantial than they were 10 years ago. There is now real potential for the dissemination of this harvesting concept for well-defined applications such as harvesting high-yielding rainfed rice.

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Development of a Motorized Ginger Slicer

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Abstract

A motorized reciprocating ginger slicer was designed and developed. The slicer was tested using "Tafin giwa" ginger for the Slicing Efficiency (SE) and Percent Damage (PD). Results showed that higher slicing efficiency was obtained at higher moisture content (76.8% SE at 30% M.C(db) and 64.6% SE at 22% M.C(db), respectively). Also, the percent damaged was lower at higher moisture content (23.2% PD at 30% MC(db) and 35.4% PD at 22% MC (db)). A comparative study of the economics of using the motorized slicer and the conventional traditional manual slicing showed it is cheaper to use the motorized ginger slicer at ₦176.46 per ton while the traditional manual slicing is ₦314.92 per tonne.

Introduction

Ginger (*Zingiber offininale* Roscoe) is an important source of foreign exchange to Nigeria. It is grown all over the country but most largely produced as a cash crop in the southern part of Kaduna State, namely; Jaba, Jema'a and Kachiya Local Government Areas. It is an annual crop propagated vegetatively to yield fleshy underground rhizomes (Ebewele and Jimoh, 1988). The branching fleshy rhizomes have a sweet spicy pungent flavour composed of 40-60% starch, 10-40% yellow colour volatile oil responsible for its flavour and the remaining percentage for protein, mineral matter and fibre content (Charan, 1995). Ginger is used essentially as raw material in the food, confectionary, perfumery, pharmaceutical and wine industries (Akumas and Oti, 1988).

Ginger enters the international markets in fresh (green), preserved and dried forms. However, the most important commercial form is the dried ginger (split or whole), ground as spice and for extractives - ginger oil and ginger oleoresin. Split dried ginger commands higher prices in the market because the pungency reduction is less and it has pleasing combination of aroma, flavour and pungency (Ebewele and Jimoh, 1988).

Slicing is a mechanical separation process on a solid body using cutting tool whose wedge formed cutting parts are under pressure and overcome the cohesion of the material due to the higher specific normal and thrust forces along the cutting edge. Slicing cut requires less power than non-slicing cut. The knife in slicing but has a component of velocity in the direction of the edge. The moisture content and the cross sectional areas have significant influence on the cutting energy. The cutting energy is directly proportional to the cross-sectional area and inversely proportional to the moisture content (Prassad and Gupta, 1975). Other parameters influencing cutting are the cutting velocity, shear angle of cut and bevel angle of the knife (Balasubramanian *et al.*, 1993 and Kachru *et al.*, 1996).

The mechanization of ginger production and processing has received little attention in Nigeria. Its production operations needs to be mechanized to increase the production and use (Nwandikom and Njoku, 1988). Presently, slicing of ginger is done mostly by women and children manually using knives. This poses danger to individual for injuries are usually inflicted while slicing the ginger fingers with sharp knives when holding the rhizome on the palm. At the same time the present traditional method makes the operation very labourous, time consuming and the slices obtained are irregular. In recognition of the constraints imposed by the manual method of slicing ginger which is harzadous, time consuming and labour intensive, an appropriate motorized ginger slicer for small scale farmers was developed using locally available materials.

Materials and Methods

Ginger possess some unique characteristics which were taken into consideration in designing the slicer viz: ginger rhizomes have irregular shapes and sizes, it has fingers and is highly fibrous.

The Slicer Design

Slicing, which cut the rhizomes by impact is considered appropriate based on the above consideration. The slicing mechanism performs both transitional and reciprocating motion.

$$N_1D_1 = N_2D_2 \quad \text{.................... (1)}$$

where

N_1 = motor (Electric) speed = 1420 rpm

N_2 = shaft speed?

D_1 = effective diameter of smaller pulley connected to the motor = 0.051m

$$N_2 = \frac{N_1D_1}{D_2} = \frac{1420 \times 0.051}{0.18} = 402.33\text{rpm}$$

D_2 = effective diameter of larger pulley = 0.18m

The shaft speed is equal to free wheel speed.

$$N_3D_3 = N_4D_4 \quad \text{...................... (2)}$$

where

N_3 = free wheel speed = 402.33 rpm

N_4 = crank shaft speed

D_3 = effective diameter of the free wheel = 0.072m

$$N_4 = \frac{N_3D_3}{D_4} = \frac{402.33 \times 0.072}{0.172} = 168.42\text{rpm}$$

D_4 = effective diameter of the sprocket = 0.172m

The crankshaft speed is transmitted directly to the piston by the connecting rod. Therefore, the sliding speed of the piston is 2.8 rps.

The velocity ratio (VR) of the motor speed to the crankshaft speed is

$$\frac{N_1}{N_4} = \frac{1420\text{rpm}}{168.42\text{rpm}} = 8.4:1.8:1$$

The piston stroke S = 2r

where

r = crank radius = 0.075m

S = 0.15m

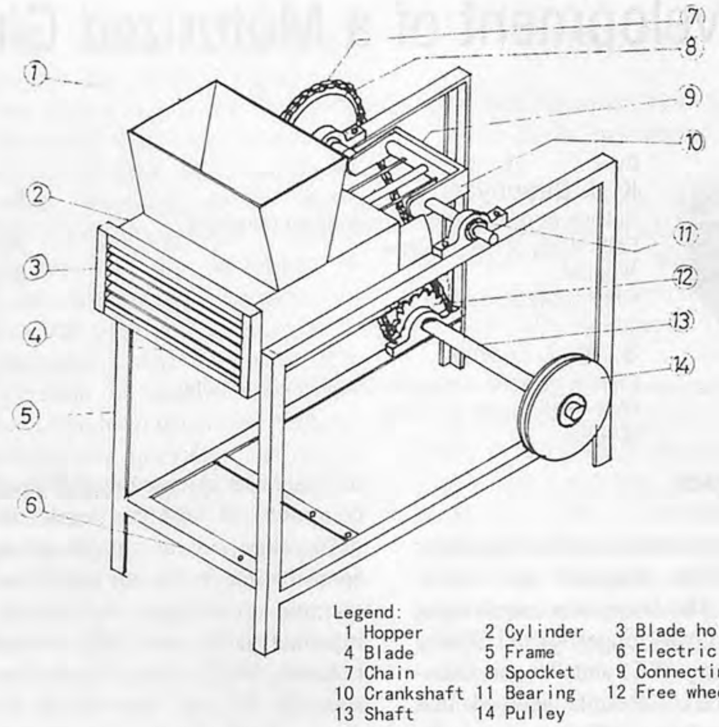

Fig. 1 Isometric drawing of the slicing mechanism.

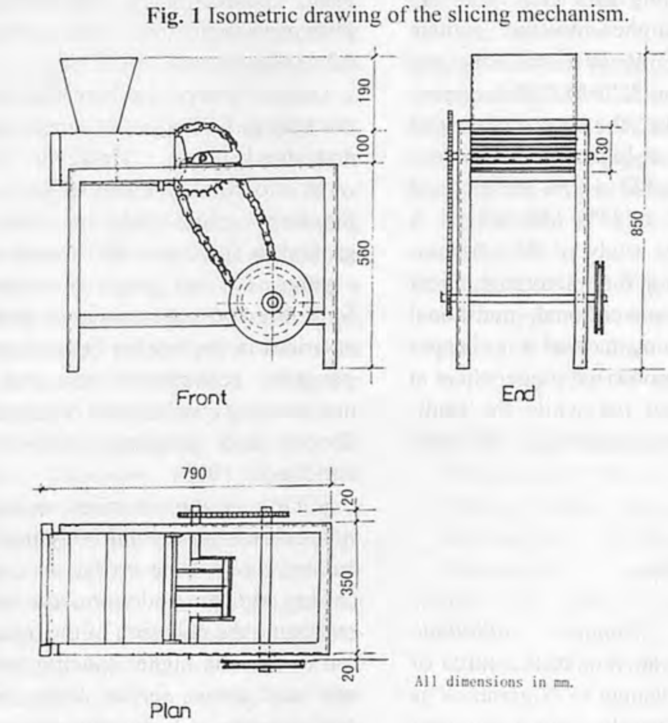

Fig. 2 Orthographic view of the slicer.

Description of the Slicer

The machine consists of the feeding unit, slicing mechanism, driving mechanism, frame and the housing. **Figs. 1** and **2** show the isometric and the orthographic views of the motorized ginger slicer, respectively.

Feeding Unit

- The hopper is a frustrum with a rectangular base dimensioned 280 mm by 200 mm at the top and 280 mm by 10 mm at the base. It is constructed from 2 mm thick sheet metal. The ginger rhizomes are introduced through the hopper to the cylinder by gravity.

Slicing Mechanism

- This comprises the cylinder, piston, connecting rod, crankshaft, blade separators and blade holders.

The Cylinder

- The cylinder is rectangular box like structure with two open opposite sides dimensioned 420 mm by 560 mm by 140 mm. It has 280 mm by 100 mm for the rhizomes intake through the hopper into the cylinder.

The Piston

- This is the main component of the slicer. The piston reciprocates within the cylinder from the Top Dead Centre (TDC) to the Bottom Dead Centre (BDC). It opens the inlet space to receive ginger rhizomes from the hopper to the cylinder at the bottom dead centre of its intake stroke. It closes the inlet space, pushing and forcing the rhizomes against the fixed blades for slicing, ejecting the slices at the top dead centre of the compression stroke. The clearance between the TDC and the blades is 3 mm.

The piston is rectangular with attachment for the gudgeon pin, a shaft on which the connecting rod turns when transmitting power from the crankshaft. It is constructed using 2 mm sheet metal folded to 270 mm by 150 mm by 130 mm with 185 mm by 120 mm flange at the sides to guide it in the cylinder.

The Connecting Rod

- This transmits the rotary motion of the crankshaft to reciprocating motion of the piston. The pins attach the connecting rod to the crankshaft and piston. The pins are separated by a 22 mm diameter pipe 150 mm long and reinforced by two – 10 mm diameter rods at the two sides.

The Crankshaft

- This unit translates the rotary motion of the electric motor to reciprocating movement of the piston. It has a central shaft 20mm diameter with projected pins constructed with flat bars. Two arms shafts are welded on the flat bars at right angles to connect bearing for effective turning and attachment of sprocket. The distance between the central shaft and the arm shafts indicates the radius of the piston stroke which is 75 mm.

Blades

- The slicer has fixed stationary blades for cutting the rhizomes. The blade constructed with stainless steel to prevent corrosion is 1 mm thick with 22^{o} blade bevel angle at one edge. It is 320 mm by 20 mm with two 10 mm diameter hole drilled for blade holder.

Blade Separators

- These separators determine the thickness of cut indicated by the clearance between the blades. The separator is 2 mm thick, 20 mm squared metal with 10 mm diameter hole at the centre.

Blade Holder

- Two 25 mm U shaped structures welded to the front of the cylinder acts as the blade guide. The blades and the separators are arranged horizontally between the holders. Two long screws hold the blades firmly in position.

Drive Mechanism

- The ginger slicer is powered by a single phase 50 Hz-1420 rpm rated 1.5 kW electric motor. The motor was mounted on the frame to help stabilize the machine.

Frame

- The frame positions all the machine components to perform its operation satisfactorily. It is 70 mm by 220 mm by 650 mm constructed from 25 mm by 25 mm angle iron.

Housing

- This comprises a metallic frame of 25 mm by 25 mm angle iron and wooden cardboard covers. The side covers were perforated to provide adequate ventilation to the prime movers. It is a 750 mm by 550 mm box meant to minimize mechanical accidents during operations and reduce environmental effects on the machine.

Evaluation of the Prototype Slicer

Tests were conducted on the developed slicer to evaluate the effectiveness of the machine to slice ginger rhizomes. Two levels of

Fig. 3 Photograph of the slicer assembly.

Fig. 4 Samples of sliced dried ginger.

moisture contents - 30% (db) and 22% (db) were used to evaluate the Slicing Efficiency (SE) and Percent Damage (PD) of the machine. Three replications were taken for each dependent variable measured. The speed of the ginger slicer and the feed rate were kept constant during the operation. **Fig. 3** shows the slicer assembly.

The ginger variety used for the test was a fully matured "Tafin giwa" bought from Kafanchan market, Kaduna State, Nigeria. The rhizomes, fed manually into the hopper, falls by gravity into the cylinder at the bottom dead centre of the piston. It is pushed horizontally to the stationary knives as the piston moves toward the top dead centre. The pushing from the rhizomes forces the sliced ginger through the blades. The slicing is longitudinal.

A known weight of ginger rhizomes were fed into the slicer at a time. The slicing time was recorded by a stop watch. Properly sliced, partially sliced and pounded rhizomes were each collected and weighed. The partially sliced were manually sliced and weighed. The moisture content of samples were determined in air oven at 130 ℃ for 24 hours. **Fig. 4** shows the samples of sliced dried ginger.

The **parameters** were used for the test; Bevel angle of the knives fixed at 22° ; shear angle - 90° ; piston speed, fixed at 168.42 rpm.

The economics of the developed ginger slicer was compared with the conventional manual method presently used. The following were considered for the evaluation:

i. Interest rate = 30%
ii. Annual repairs and maintenance = 5% of investment cost
iii. Number of working hours per year = 384 hrs
iv. Shelter = 02%
v. Effective capacity - Manual 120kg/hr
Motorized 560kh/hr
vi. Labour cost = ₦300 per man/day
vii. Cost of machine, including accessories = ₦15,000.00

$$\text{Slicing Efficiency (SE)} = \frac{W - Wd}{W} \times 100 \quad \cdots\cdots (3)$$

where
W = weight of all slices
Wd = weight of damaged slices

$$\text{Percent Damage (PD)} = \frac{\text{Weight of damaged ginger}}{\text{Weight of all slices}} \times 100 \quad \cdots\cdots (4)$$

Pramaters

Table 1. Performance Evaluation of the Motorized Slicer

Item	22% MC db (Average)	30% MC db (Average)
Wt of ginger completely sliced (kg)	7.9	10.9
Wt of ginger partially sliced (kg)	1.7	2.9
Wt of damaged ginger (kg)	3.4	3.2
Slicing efficiency	64.6	76.8
Percent damaged (PD)	35.4	23.2

Table 2. Comparative Economics of the Motorized Slicer with Conventional Manual Slicer

Description	Motorized Slicer (₦)	Traditional Manual Slicer (₦)
1. Cost, including all accessories	15,000	100
2. Annual fixed cost		
- Interest (30%)	4,500	-
- Depreciation (10%)	1,500	10
- Repairs and maintenance (5%)	750	5
- Shelter (2%)	300	-
Total annual fixed cost	22,500	115
Fixed cost per hour	57.42	0.02
3. Operating cost/hr		
- Wages to labour/hr	37.5	37.5
- Cost of electricity/hr (1 kw/h =₦2.60)	3.9	-
Total operating cost/hr	41.4	37.5
Total slicing cost/hr (2+3)	98.82	37.79
4. Slicing cost for one ton of ginger	176.46	314.92

[$ = ₦120]

Results and Discussion

The performance of the developed ginger slicer was evaluated. **Table 1** gives the result of the test. The effect of the moisture content on the slicing efficiency and percent damage was evaluated. The moisture content has a considerable influence on the slicing efficiency. At high rhizomes moisture content 30% (db) the slicing efficiency of the machine was 76.8%. At a lower rhizomes moisture content of 22% (db), the slicing efficiency reduced to 64.6%. The water molecules in the fibrous ginger rhizomes influences the ease of the knife passing through the rhizomes. The fibrous nature of the rhizomes makes slicing to be difficult at lower moisture content, thereby increasing the rhizome damage. At 22% (db) rhizome moisture content, the percent damage was 35.4%. There was a reduction in the rhizome damage at higher moisture content. The percent damage was 23.2% at 30% (db) rhizome moisture content.

Comparative analysis of the economics of the developed ginger slicer with the conventional manual method presently used is shown in **Table 2**. The time taken to slice the ginger rhizome and the cost reduced when using the motorized machine. The machine sliced ginger rhizomes were of more uniform sizes than the manually sliced ginger rhizomes. The uniformity in size aid even drying of slices. Despite the initial cost of the motorized slicers which is high, the cost of slicing one ton of ginger rhizome by the machine was lower than the conventional manual method. The slicing cost per ton was ₦176.46 for the ginger rhizome and ₦314.92 for manual method. With more annual usage, by custom, the cost per ton can when using the motorized slicer be further reduced. Also the hazard of the possibility of being injured when using sharp knives when using the conventional manual method was removed.

The developed motorized slicer has the following advantages over the present conventional manual slicing.

i. The safety of the operator is assured.
ii. It is easy to operate and transport from place to place.
iii. Various sizes and shapes of ginger can be accommodated.
iv. It produces slices of more uniform thickness.
v. It can be operated by unskilled labour.
vi. Co-operative farmers, medium and large scale entrepreneurs stand to benefit from the slicer.

Conclusion

A motorized ginger slicer was designed and developed using locally available materials. Reciprocating principle with fixed blades was adopted.

Results showed that the slicing efficiency is dependent on moisture content of the rhizomes: 76.8% slicing efficiency at 30% MC (db); and 64.6% slicing efficiency at 22% MC (db). The slicing efficiency is higher at higher moisture content.

The result also showed that percent damage is dependent on moisture content of the rhizomes. The percentage damage of 23.2% at 30% MC (db) while 35.4% percentage damage at 22% MC (db) more pounding of ginger rhizomes was obtained at lower moisture content.

Comparative analysis of the motorized ginger slicer and the conventional manual method showed the motorized slicer is better in cost, uniformity of slices and timeliness than the manual slicer. The developed slicer is recommended to the co-operative farmers for adoption.

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Agricultural Mechanization in Botswana: Better Agricultural Production in the New Millennium

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Abstract

Although the agricultural sector in Botswana has grown by 17 % since independence, its contribution to the GDP has declined drastically. This paper addresses issues that are crucial in reviving this sector. These may include the formulation of a sound mechanization policy, provision of supporting infrastructure and institutional restructuring. Most of these issues are examined by comparing the present situation in Botswana and Africa as a whole with other continents, which have had a turn around in agricultural production.

Introduction

Botswana is a semi arid country with rainfall averaging 250 to 650 mm per year. Its population is estimated at 1.3 million (CSO, 1991) of which about 50 % will live in rural areas by 2003 and derive their livelihood mainly from agriculture. The country occupies between 17°and 27°S latitudes and 20°and 30°E longitudes and covers an area of 582000 km^2 and is landlocked by South Africa, Namibia, Zimbabwe and Zambia (**Fig. 1**).

Botswana is Africa's 3rd economically prosperous nation and is one of the fastest growing economies of the world. Crop production in Botswana is largely constrained by, below average rainfall, lack of timely tillage and ploughing operations to optimize available moisture. The major crops grown are sorghum, maize, millet, beans/pulses, sunflower and groundnuts. **Fig. 2** shows the trend in production of four major crops in the country from 1979 to 1995 (BASR, 1995).

The periodic nature of production is testimony to rainfall pattern as much of the production is under rainfed agriculture.

Agriculture's contribution to

Fig. 1 Map of Botswana.

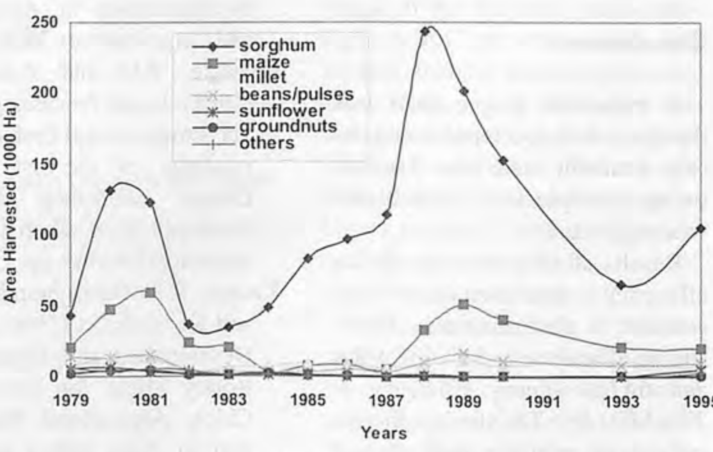

Fig. 2 Production of four major crops in Botswana (Source: BASR 1995).

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GDP has declined from 40% at independence in 1966, when they were very few productivity activities, to 2.9 % in 1998/99 (MTR-NDP8, 2000). Although, there are many other constraints that might have equally profound effects on crop production, this paper addresses the farm mechanization constraints.

According to the 1995 agricultural survey report (BASR, 1995), there were a total of 144,440 traditional agricultural holders. About 47 % of these were cultivating 0.1-1.0 ha plots accounting for only 0.7 % of the total production of the four major crops grown in Botswana. It is interesting to note that holdings of 4-6 ha accounted for 20% of production with almost double production per hectare when compared with the smaller holdings. Similar results have been reported in Pakistan where yield per hectare from animal powered fields was less than that of tractor farms. Moreover, fertilizer application was also less efficient as reflected in the yield values (Ahmad, 1983). The objective of this work was to study the present status of agricultural mechanization in Botswana and address the mechanization issues that are crucial in reviving the agriculture sector.

Historical Perspective

Agricultural mechanization in its broadest sense implies the use of mechanical contrivances which give an advantage in the use of power for work be it human, animal or mechanical power (Shrivastava and Shrivastava, 1998). It is one of the vital inputs for timeliness of farm operations and in reducing post-harvest losses (Verma and Singh, 1994).

In Japan, like in North America, mechanization was a direct result of efforts to reduce farm drudgery and substitute for shrinking agricultural labor force. The transformation or improvements in agriculture had both the inputs from farmers and farm machinery industry and the government (BASR, 1995). Rapid development of farm mechanization can only be due to the efforts of farm machinery industry geared to meeting farmers' needs and demands. There is a common concern in urban migration in developing countries, hence it can be assumed that with time the farm labor will decline and hence mechanization will be a necessity. Botswana is no exception; the white paper on industrial policy is a clear indication that increasing the industrial base will eventually tap on the labor market of which the farming community has relied on for decades.

In Africa, there has been a lot of disappointing results in large scale, heavily mechanized farming. These include Tanzania in the 1940s where 1 million ha of land was to be put under groundnut production (BASR, 1995) and more recent Pandamatenga farms in Botswana. There are other countries where wars have affected agricultural production drastically. Some of the contributing factors to the failure of these schemes are: lack of infrastructure; machines not suitable for local conditions; lack of spare parts and servicing facilities; and lack of trained personnel to operate the machines.

Recently, some countries were trying to rehabilitate large stocks of disabled machinery which have been lying for years since the projects failed. These failures are not normally thoroughly analyzed and this has led many countries in Africa to reinforce the promotion of draught animals with locally manufactured equipment. The authors think that solutions should be sought to remedy the problems and reserve animal draft to a very small percentage of subsistence farmers. The answer to all the four points outlined above is that governments should initiate comprehensive mechanization policies. **Figs. 3** and **4** show the field sizes against yield per hectare and field sizes against percentage holding, respectively.

From the information above, the following observations are made, especially in the traditional holdings:

1. It is widely accepted that animal draft power is suitable for small holders, because of the minute production, but this might not be the case. No matter what power unit is employed, the bottom line is efficiency. It might be true that small rural farmers can afford animal draft power, but issues like this ask if the farmers can efficiently manage animal draft power or how efficient can animal draft power be.
2. There seems to be a majority plot size of 2 to 6 ha, under the present mechanization status in Botswana indicating that animal draft power might be the major source of power utilized.
3. Although there are yield/ha targets in the agricultural policy, probably based on the Department of Agricultural Research (DAR) data or production in the commercial sector, a realistic yield value for the potential dry land farming production in Botswana based more on management should be established.
4. Finally, it is the role of government to address the mechanization situation in Botswana.

Agricultural Mechanization Strategy

The first step in making public polices and adopting new strategies is to review the present status of agricultural mechanization in the country. In the Botswana National Development Plan (BNDP, 1997); the agricultural research and technology development statement is vague. The statement reads "... To systematically prioritize research efforts and develop strategic plans, a research master planning exercise will be undertaken to set short, medium and long term plans for the department of agricultural research. These areas of concentration will continue to be irrigation management, agricultural mechanization...".

It should be made clear that agricultural production needs "power or energy input". This component is normally ignored because developing countries in Africa do not have as many engineers as agronomists at the decision making level, which lead to extension specialists to run the show. It is estimated that 30 % of all investments required in agriculture in the developing countries is for agricultural machinery (FAO, 1986), so government initiatives should reflect this need. Mechanization is not one individual sector undertaking; it is vital to have mechanization included in the industrial policy. Although this is implied in the main themes of the draft paper, it should be made clear that agriculture, manufacturing, water and energy, transport and communication, and financial institutions sectors are all required if a comprehensive mechanization policy is to be developed.

The government should come up with an agricultural policy which will create a great demand for farm machinery. This policy should introduce methods of production and management which justifies mechanization effort. These policies aimed at modernizing farms should provide subsidies to supply credit and other kinds of assistance to farmers and rural manufacturing industries. It has been reported that in India, the easy availability of the agricultural credit has contributed significantly towards the growth of the tractor industry where more than 90 % of tractors are sold on credit (Singh and Doharey, 1999).

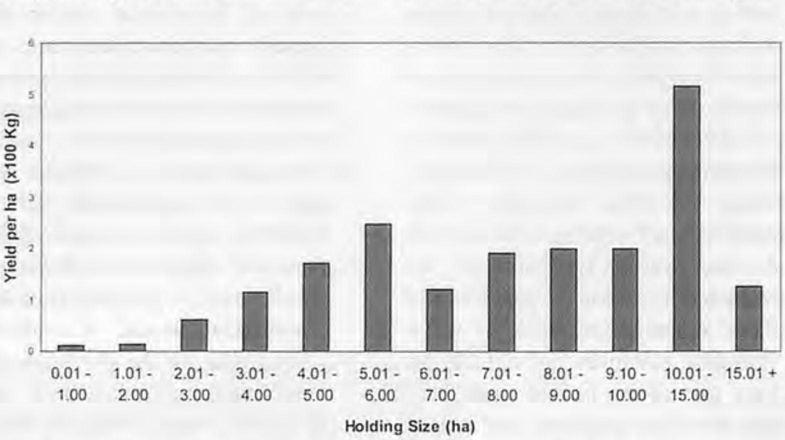

Fig. 3 Distribution of field sizes and respective production for four major crops grown in Botswana.

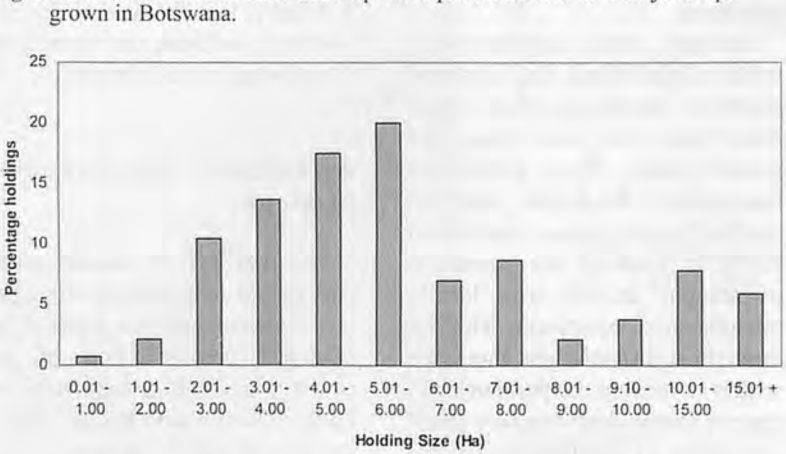

Fig. 4 Distribution of field sizes as cultivated by traditional holders.

Estimation of Energy Need in Botswana Agriculture

The extent of farm mechanization in any country depends mainly upon the availability of power on the farm to carry out different operations (Verma and Singh, 1994). Energy utilization at the farmers' level might involve heating (cooking and drying of crops), running stationery engines for size reduction and processing and operating mobile machines for field operations and transport of farm produce and goods (Nath, 1998). However, the present discussion includes farm operations exclusively related to crop production system and an estimation of energy requirement is provided.

Human power

At present the total population of the country is 1.3 million and about 48 % of the population live in rural areas. According to Makungu and Dihenga (1995), a human being is rated at about 0.10 kW and as such an input of 62,400 persons shall be 6,240 kW, assuming that 1/10 of the rural population is engaged in farming at any time (Nath, 1998). The human power contributes about 6.2 % of total power available for agriculture. Operations like sowing, transplanting of crops and vegetables, hoeing, weeding, harvesting, etc. are best performed manually (Verma and Singh, 1994).

Animal power

It is estimated that there are about 3 million cattle in Botswana of which 10,000 are working on farms as draft power. A single cattle has the capacity of about 0.50 kW (Makungu and Dihenga, 1995) and as such an input of 10,000 head of cattle shall be 5,000 kW. The donkey population in Botswana is 230,000 (Mahapatra and Kumar, 2000). If the services of 23,000 head of donkeys are available, it will add to another 9,200 kW assuming an average power production of 0.40 kW (Makungu and Dihenga, 1995) per work donkey. Draft power is used for ploughing, transport to collect water and movements of family to and from the cattle posts and lands (Mrema and Patrick, 1991).

Tractors

Tractors play an important role in the development of Botswana agriculture. FAO estimates indicated that there were 6,000 tractors and 95 harvester-threshing machines (a tractor for 20 agricultural holders) for agricultural use in Botswana in 1996. This was an increase of 64 % since 1980, compared to 22 % increase for Africa (FAO, 1997). If only 4,000 tractors are in use at any one time and each tractor is at least of 20 kW capacity, total tractor power available then becomes to 80,000 kW. The total imports of tractors between 1994 and 1999 are presented in **Fig. 5**. It was impossible to quantify and compare the diversity in the intended use of tractors imported, due to unavailability of reliable records. It appears that most of these tractors were to be employed in construction and not in agriculture.

Of the total land area, only 29,0592 ha is under crop-land (BASR, 1995). Now assuming a minimum power requirement for an effective agriculture is 0.75 kW/ha (Davie, 1973) a total of 217,944 kW is indeed required, leaving a deficiency of 117,504 kW, which is about 54 % of the total requirement.

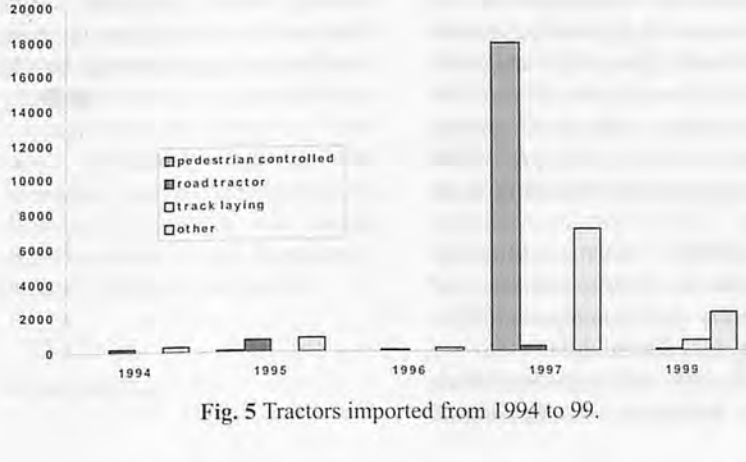

Fig. 5 Tractors imported from 1994 to 99.

Human Resource

Compounding the problems of mechanization is the lack of agricultural engineers in Botswana. The Botswana College of Agriculture (BCA) offers only a diploma course in Agricultural Engineering. Every second year there are about 10-15 diploma graduates majoring in agricultural engineering. A degree program in Agricultural Mechanization should be designed to provide a sound education in the principles of mechanized agriculture and its resources. A variety of career opportunities exist within production agriculture and related agribusiness organizations. Graduates can be employed with food and feed processing companies or with large producing farm organizations in marketing or management roles. In addition, the courses taken by agricultural mechanization students should better equip them to manage businesses of their own should they so choose.

Conclusions

Despite the decline in the agricultural sector's contribution to GDP, Botswana will for a long time depend on this sector for food, income and investment capital. Most appropriate production technology in Botswana agriculture may be a combination of manual, animal and tractor based system.

Available mechanization technologies from different parts of the world should be successfully transferred and adopted to suit local farming and manufacturing conditions. To ensure the success of a mechanization program, efforts will have to be made by institutions concerned with agricultural mechanization such as BCA and Department of Agricultural Research (DAR) to develop and adapt appropriate technologies that are consistent with the prevailing situations in Botswana. Systems and techniques developed in the industrial countries should not be adopted in Botswana without proper testing and necessary modifications.

Looking from the farm mechanization perspective, it appears that almost all the agricultural machines are imported from abroad. Therefore, a research, development and testing center purely for agricultural machines should be established at the Faculty of Agriculture to test the imported machines for their performances and can be modified to meet the requirements of Botswana.

In order to realize agricultural mechanization successfully, the training of qualified personnel of relevant disciplines at different levels is of vital importance. The development of the Agricultural Engineering discipline will greatly accelerate the pace of agricultural

Fig. 6a Donkey's used as transport.

Fig. 6b Maize Cropat the Botswana College of Agriculture.

mechanization in Botswana. This discipline has not received its due recognition.

It might be worthwhile to form a separate Agricultural Engineering Department under the Ministry of Agriculture to coordinate all the required engineering services in the agricultural sector, these include power and machinery, soil and water engineering, agricultural processing, farm structures, microprocessor applications and rural electrification.

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The Potential of Using Solar Energy for Chick Brooding in Port Harcourt, Nigeria


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Abstract

Chick brooding using kerosene, as heat source is an energy intensive process of the poultry industry with consequent air pollution. This paper presents practical measures to employ solar energy instead as an alternative energy source in this poultry process in the Port Harcourt metropolis. A building with a single gable end having a solar collector and rock-bed heat storage fitted externally to it was constructed for the brooding experiments. Stocking was of five months' duration and for over a period of two years, using 200 day–old chicks per batch. Control experiments were conducted using kerosene to compare process performances between the two sources of energy in chick brooding. The solar arrangement recorded 68% liquid fuel (kerosene) saving in relation to the conventional system. Chicks raised through the solar arrangement also scored significantly ($p = 0.05$) and were rated better in all the biological indices of performance. These results adequately expressed the economic and environmental advantage in the use of solar energy over kerosene for chick brooding in the Port Harcourt metropolis.

Introduction

Generally, egg or meat production in the poultry industry starts essentially with brooding care on the day-old chicks and continues in the growing birds. In Nigeria, the most popular source of energy for chick brooding is the petroleum fuel (mostly kerosene). Petroleum fuels are hydrocarbons which, on combustion, release gases such as sulphur dioxide (SO_2), carbon dioxide (CO_2), etc. that are environmentally unfriendly. Agu (1995) identified traces of sulphur dioxide and fumes of other chlorofluorocarbons (CFC) as products of kerosene combustion contributing, in high proportions, to the worsening overall global warming. It is also believed (Webster and Wilson, 1980) that these combustion products are potential factors in chick mortality during and after hovered brooding practice. Besides, energy used in the process of chick brooding constitutes a major cost item, rated almost at par with feeds (Ansa, 1998; Zibokere, 2000). Available data (FRN, 1997) indicate that in 1996 alone, about 400 million chicks were reportedly produced in Nigeria with an estimated attendant expenditure of about ₦1.7 billion (using current rates of ₦18/litre) of kerosene in addition to electricity.

With the present high cost of the conventional fuels and expected increase over time, in addition to possible shortages occurring at critical times, the use of alternative energy sources has become attractive. In 1997 a study was initiated in the Department of Agricultural Engineering of the Rivers State University of Science and Technology, Port Harcourt to determine the practicality of substituting solar energy at least, in part, for heat energy from fossil sources in chick brooding in the Port Harcourt solar zone (Akor and Ideriah, 1995). Two buildings with single gable ends were constructed for brooding experiments on 200 baby birds, run in batches in January/ February, July/ August, and December in 1998; and April/May, and September in 1999. These months were chosen to represent the rainy and dry seasons traditional in the Port Harcourt metropolis.

The objectives of this work therefore were:

i) To investigate and establish the practicality of chick brooding with solar energy in the Port Harcourt metropolis; and
ii) To develop a system for solar-assisted chick brooding and evaluate its performance.

This paper describes the pilot study of the system and its physical performance to establish the practicality of chick brooding with solar energy. The design considerations of the solar–assisted chick brooding system is considered in a separate paper in preparation.

Materials And Method

The two single gable-ended brooder structures (**Fig. 6**) were constructed to allow comparison of two systems of brooding:

i) Use of conventional kerosene stoves; and

ii) Use of solar plenum heating technique.

The solar brooding and the fossil fuel (conventional) brooding systems were placed close to each other. Each of them has 16m^2 of floor area providing enough space for 200 baby birds up to six weeks of age.

A 1.35m^2 flat plate collector was connected to the solar brooding house. It was made active using a gentle speed, low volume AC/DC fan transferring the heat from the collector to the brooding chamber via a 2m^3 (2740kg/m^3) rock bed heat storage (**Fig. 1**).

The collector's angle of tilt (β) of 17° facing south to enable it 'see' the sun for about 8 - 10 sun shine hours was used. Two, 4-litre kerosene stoves were on the stand-by in the solar brooding house to provide auxiliary or supplementary heating at periods when the heat from the solar arrangement becomes critically inadequate.

Instrumentation

Liquid-in-glass thermometers placed at the top, midway and bottom of the brooding chamber were used to sense chamber temperature. Plenum temperature was regulated by opening or closing louvered windows and cork ports.

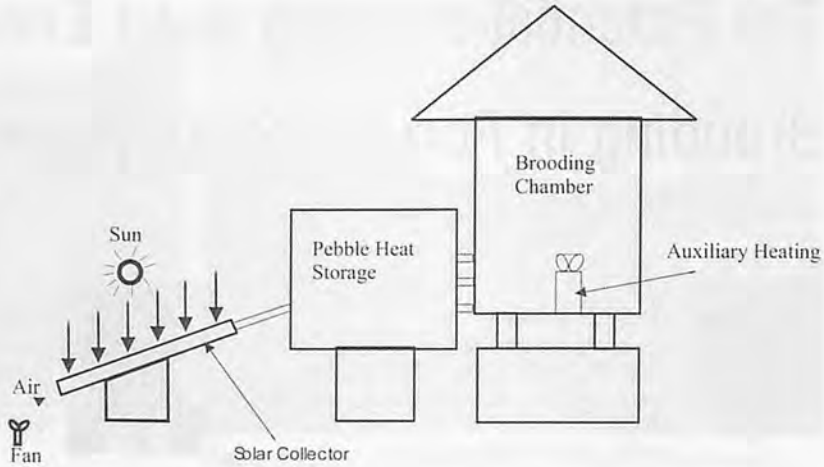

Fig. 1 Schematic arrangement of the solar brooder.

In the solar arrangement, heated air is conveyed actively through the rock bed to the brooding chamber. The difference in temperature between the plenum, rock bed and ambient as sensed by one copper–constantan thermocouple placed in each of these points, actuated a differential temperature controller (set at 38 ℃) connected to the micro–switch system of the AC/DC. These measures were taken in both structures to keep the plenum temperature maintained at or close to 38 ℃ The chicks were bred for 28 days with all husbandry procedures strictly observed on both systems.

Procedure

During each test, temperatures were recorded at 5-minute interval during the first two weeks and increased to 30 minutes afterward. According to Clark and Amin (1985), brooding temperature is a critical factor mostly in the first two weeks of the birds' life. As they grow older and feather out, brooder temperature becomes gradually less critical. Heat energy calculations were based on an average of the difference between the plenum temperature and ambient.

At the conclusion of each brooding test, 50 birds were randomly taken from each system for biological analyses while economic analysis was based on difference in kerosene consumption of both systems. Data were subjected to analysis of variance (ANOVA) and the performance of the solar arrangement was compared to the conventional kerosene system using paired – t for test of significance.

Results and Discussion

Ten tests were run between 1998 and 1999 to compare the two systems of heating in chick brooding. The thermal performance of the so-

Table 1. Mean Maximum Plenum Temperatures in the Unstocked Solar Brooder

Flock title	Mean maximum collector outlet temperature, ℃	Mean maximum plenum temperature, ℃ *	Mean collector efficiency, %
Jan., 1998	71	61	48.1
July, 1998	69	59	47.7
Dec., 1998	71	63	48.1
Apr., 1999	69	60	46.9
Sept., 1999	68	59	48.5

* When 90% of all ports were closed.

Table 2. Thermal Performance of the Solar Brooder for the 28-day Brooding

Flock title	Total solar heat collected W/M^2	Total solar heat delivered, W/M^2	Total supplementary heat applied, W	Solar %
Jan., 1998	398.83	390.44	85.50	82.0
July, 1998	408.28	363.02	142.50	71.8
Dec., 1998	404.53	399.76	74.10	84.4
Apr., 1999	408.21	387.38	96.00	80.0
Sept., 1999	408.71	367.58	171.00	68.3
Mean	405.71	381.83	114.00	77.0

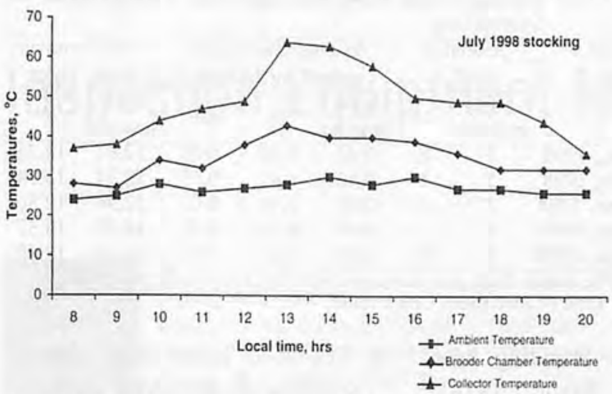

Fig. 2 Mean thermal performance of the solar arrangement per stocking period in 1998.

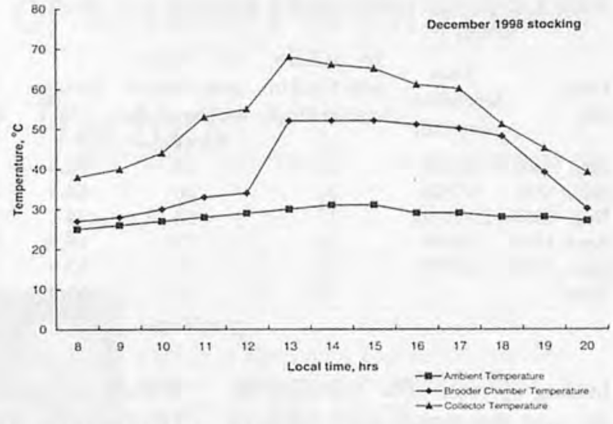

Fig. 3 Mean thermal performance of the solar arrangement per stocking period in 1998.

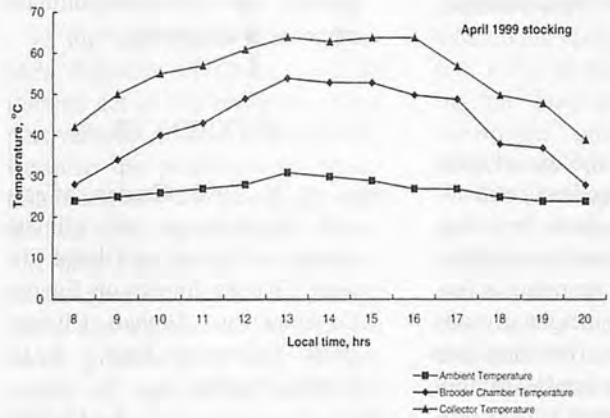

Fig. 4 Mean thermal performance of the solar arrangement per stocking period in 1999.

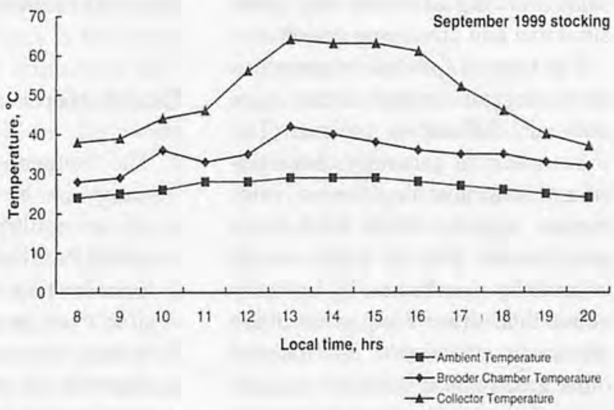

Fig. 5 Mean thermal performance of the solar arrangement per stocking period in 1999.

lar arrangement with no chicks in the brooding chambers is summarized in **Table 1**. **Figs.** 4 and 5 give the thermal performance of the solar arrangement without the chicks for two arbitrarily chosen days of each stocking period. There is clear indication that the solar heating arrangement for chick brooding was adequate considering that the birds need a minimum plenum temperature of about 34 − 36 ℃ to brood comfortably. When almost all vents were closed on the solar brooder house, the performance curves in **Figs. 2** to **5** indicate the highest brooder plenum temperature occurred in the late harmattan (December/January) flock and minimum in the September stocking period. This range yielded an overall mean percent solar of about 77% as shown in **Table 2**. Percent solar (ϕ %) is here defined as

$$\varphi\% = \frac{\text{Solar heat applied}}{\text{Actual heat used}} \times 100$$

The implication of this is that the solar arrangement would unavoidably require supplementary heat supply from the other fuel sources (usually kerosene).

The rate of kerosene consumption on both systems of brooding is summarized in **Table 3**. The solar brooder consumed, on the average, 68% less kerosene than the non-solar arrangement. The tremendous savings by the use of solar energy results in an economic advantage of the system over the use of kerosene. It also proves to be a feasible approach of reducing dependence on the rather expensive, non-renewable and environmentally questionable fossil fuels for brooding. Rokeby et al (1983) and Riley and Redfern (1977) also reported similar reduction in fossil fuel used for solar assisted livestock keeping in Arkansas, United States.

Biological Performance of Birds Raised through the Solar Brood

Three basic indices were used to appraise the biological performance of birds raised through the solar brood system (**Table 4**), showing that in all the biological indices of performance used, the birds on the solar brooder obtained highly significant ($p = 0.05$) values over the conventional non-solar

Table 3. Kerosene Consumed in the Solar and Non-solar Flocks

Flock title	Date Stocked (as day-old)	Vol. of Kerosene Used in the solar Flock, L	Vol. of Kerosene Used in the Non-Solar Flock, L	Savings %
Jan., 1998	6/1/98	20	68	70.6
July, 1998	8/7/98	31	86	64.0
Dec., 1998	29/12/98	15	58	74.1
April 1999	7/4/99	22	73	69.9
Sept., 1999	23/9/99	33	91	63.9
Total		24	75	68.0

Table 4. Biological Performance Record of the Solar Brood Chicks Compared with those of an Equivalent Conventional System (cs)

Flock title	Mortality rate*, %		Average live weight gained, kg/10 birds			Feed** conversion, kg/kg	
	Solar brooder	cs	Solar brooder	cs	diff.	Solar brooder	cs
Jan., 1998	3	8	0.48	0.48	0.01	12.81	12.76
July, 1998	5	8	0.46	0.41	0.05	13.94	13.74
Dec., 1998	2	4	0.49	0.46	0.03	12.96	12.86
Apr., 1999	4	7	0.47	0.45	0.02	14.75	14.37
Sept., 1999	6	9	0.44	0.43	0.01	14.22	13.92

* The initial flock size per period was 200 baby birds per flock.
** Type of feed used, Chick mash.

heating system. The mortality index was also significantly lower (p = 0.01) as the solar arrangement recorded only 4% deaths against 8% in the non-solar system, presenting solar brooding of chicks as a more attractive and promising option.

The reasons for these expressions of biological improvement were however, difficult to explain. The solar option is generally characteristic of minimum negative environmental impact. Birds bred in an environment free of HAPs would expectedly perform biologically better than those bred where there are traces of sulphur dioxide and other green house influencing gases spewed constantly through burning of hydrocarbon liquid fuels. Respiratory diseases are mentioned to be most prevalent in poorly ventilated brooding pens where kerosene is burned to provide brooding heat (Williamson and Payne, 1978). Rokeby et al. (1983) made similar observations on broiler stock, Schulte et al. (1989) on swine nurseries and Jordan (1979) on turkeys.

Conclusion

1. The frontiers of the use of solar energy can be practically extended to poultry chick brooding within Port Harcourt metropolis.
2. Solar heating for brooding is feasible even in the height of rains in this solar zone. Brooding data obtained in the heavy rainfall months of July and August provide this evidence.
3. Significant fuel savings was achieved in the solar arrangement.
4. The solar brood birds showed significantly less chick mortality and better feed conversion and average weight gain. These biological improvements were reasonably due to the non-pollutant nature of solar energy.

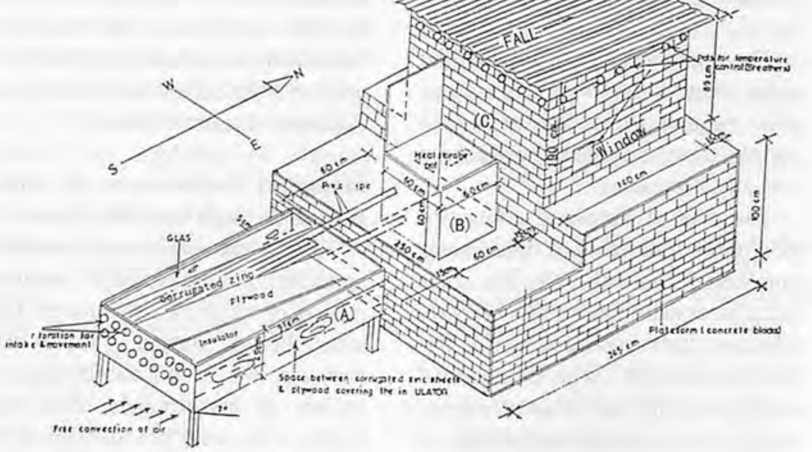

Fig. 6 Assembly of the components.
A: Solar energy collector B: Heat storage pot C: Brooding structure

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Design and Development of Mobile Performance Inspection Equipment for Tractors

by

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Abstract

In the vast countryside in People's Republic of China, most of tractors act as the important transport vehicles, instead of field work. Because the performance inspection of tractors was usually ignored, the bad working condition of tractors have resulted in the problems of environmental pollution, energy waste and transport accidents. All-level governments and departments of agricultural machinery management have taken measures to inspect the performance of tractor at least once a year. A new-type equipment was developed for the need of management departments. According to the trial check, the accuracy of braking torque is 0.1 kg · m; the accuracy of axle weight is 0.1 kg; the accuracy of driving speed is 0.01 km/h; the time spending in inspecting a tractor is 3 minutes; more than 150 units can be inspected every day. The results of practical application proved that the equipment was suitable as an inspection tool.

There are over 15 million tractors in P. R. China. According to the statistics of the Tractor Information Net, the production in 1998 was 1,781,200 units. The tractor is used as a main transport tool in the vast countryside. Only a few tractors serve as field implement during the busy-season. The tractor contributes greatly to the wide countryside's prosperity.

With the rapid increasing numbers of tractors, the problems of pollution and transport accident are serious due to bad performance condition of the tractors. The performance of the tractors decreased and deteriorated quickly without being often inspected and repaired. In the light of environment protection, saving energy and transport safety, all-level departments of agricultural machinery application and management have taken a step to inspect the tractor performance once a year and to improve their performance. A set of suitable test equipment is needed immediately.

Structure and Principle of Inspection Equipment

Based on the requirement of administrative department, 6 main programs are inspected. The Test Report includes the judgement criteria of qualified tractors taking the typical 8.8 kw small-type tractor, for example (**Table 1**). Among these programs, the inspection of the braking performance is mostly emphasized. According to statistics, about 30% of transport accidents were due to bad braking performance.

Fig. 1 shows four main parts of the equipment: test instruments system; data information measuring, gathering and A/D transfers system; microcomputer operation platform and electrical and hydraulic control system. The indexes of speed, braking torque and axle

Table 1. Test Report of Tractor Performance

Driver's Name: Vehicle Number: Type: Date:

Speed (km/h)	≤40					
Front axle weight (kg)				Rear axle weight (kg)		
Front wheel braking torque (N·m)	Left			Rear wheel braking torque (N·m)	Left	
	Right				Right	
	Left+Right	≥front axle weight*40%			Left+Right	≥front axle weight*45%
	ABS(Left-Right)	≤front axle weight*8%			ABS(Left-Right)	≤front axle weight*10%
Lights power (100cd)	Left	100≤LP≤220	Result:×××			
	Right	100≤LP≤220				
Noise (dB)		≤86	Test station:×××			
Waste gas (Rb)		≤6.5				

Acknowledgement

The project was supported by Scientific and Technological Bureau of Zhejiang Province.

weight are measured on self-designed test platform. The indexes of waste gas, noise and light are measured by ready-made specialized equipment. The information, either picked up from test platform by sensors or output from the other ready-made equipment, is transferred into microcomputer by RS-232C serial port interaction, then the data are accepted and processed by self-developed specialized software. The software processes data and judges results according to ready-installed criteria, then prints out inspection results. This whole process is online displayed on computer screen.

Design of Test Platform

The test platform consists of five parts: braking torque test platform (I); axle weight test platform (II); driving speed test roller (III); cylinder (IV); and guide deck (V) (**Fig. 2**).

The maximum driving speed of a tractor is tested equal to the speed of the roller driven by the driving wheel of the tested tractor. The speed of the roller is measured by a sensor installed in the framework near the end of the roller.

The axle weight is measured by the sensor under the platform, in order to be used as reference to judge the braking performance of the tractor.

There are usually two methods of testing the braking torque. One is that two pairs of rollers driven by electric machine propel the braked wheels of the tractor, and the braking torque can tested by sensor. The other is that the movement of the platform propelled by force from hydraulic pump pushes the braked wheels of the tractor, and the braking torque can tested by sensor. The former has the disadvantage in that the worn out wheels are difficult to be propelled by the rollers so as to effect the testing accuracy. The structure is relatively complex.

The test platform can be lifted by four cylinders fixed in the edge of the test platform. When the four cylinders elevate the test platform to the height that is higher than the transport tool, a modified vehicle, the vehicle drive into the point with back gear under the test platform, then the four cylinders are withdrawn and the test platform can be transported. The height of the four cylinders is 1.5m each. The four cylinders can be turned down and the four guide decks are uninstalled during transporting. The unloading process of test platform from the vehicle is similar to the load process. The test platform is placed on the ground during the test. The inspected tractor drives according to the procedure from driving speed test roller to braking torque test platform.

Information Pick-up System

The structure of information pick-up system is shown in **Fig. 3**.

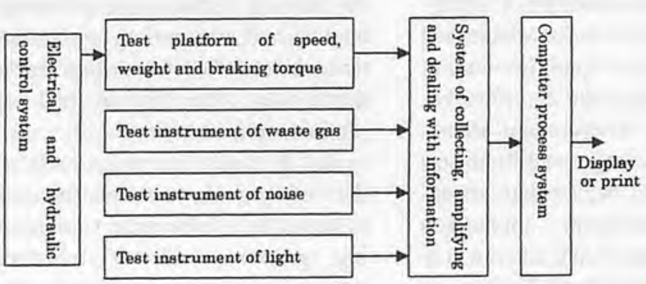
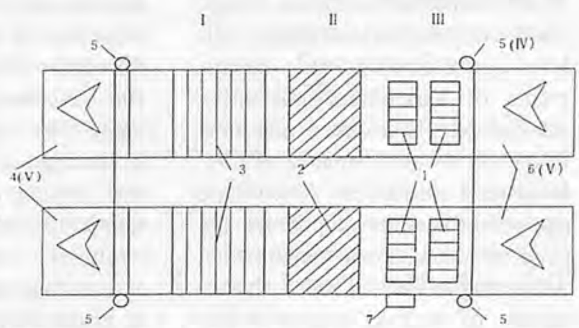


Fig. 1 Structure and principle of equipment.



Legend: 1. Roller 2. Axle weight test platform 3. Braking torque test platform 4, 6. Guide deck 5. Cylinder 7. Plate of setting sensor

Fig. 2 Structure of test platform.

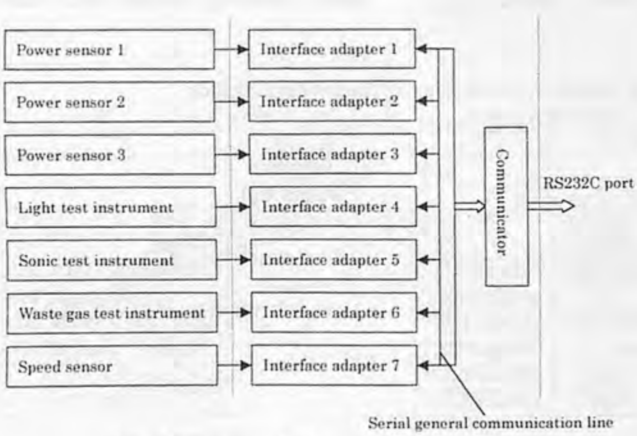


Fig. 3 Structure of information gathering.

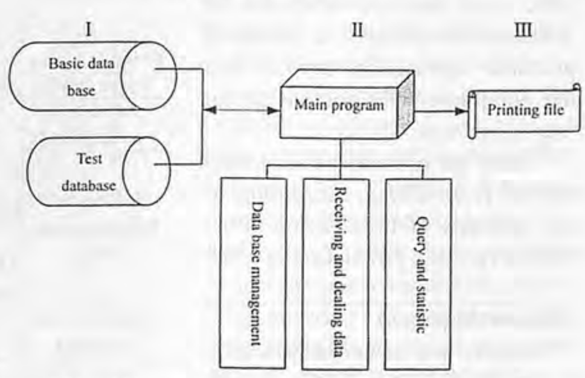


Fig. 4 Structure and principle of the software system.

It consists of seven pieces of interface adapters which are the chip microprocessors systems with 89C51 microprocessors. Its functions are mainly amplifying, A/D transferring and dealing with information from sensors and test instruments. The information from seven interface adapters is collected by the communicator, then transferred into computer by RS-232C serial port interaction.

Development of Inspection Software

Under the Microsoft Windows 95 condition, the computer language of the Visual Basic 5.0 was applied to program the software. The Visual Basic is an object-oriented and event-oriented computer language. It is popular in the world because of its powerful function and simplicity of being learned and applied.

Access 97—a powerful data base management language, was used to manage the basic information data and the data from test instruments.

The Visual Basic provides two methods to fulfill the function of long-distance communication by MSComm component: a) Event-driven communication; and b) Inquiring communication. In this software system, the first method was chosen based on the concrete condition. Inquiring communication is an effective way to deal with RS-232C serial port interaction.

The system consists of three main parts: Main program (I); Data base file (II); and Printing file (III). The details are illustrated in **Fig. 4**.

The software system is an important part of the inspection equipment. It has a friendly and simple operation interface and high operation reliability and can be easily operated even by the people who lack computer knowledge. The driver can witness the whole test process in the computer screen. Its functions are as follows:

1. Managing basic tractor information, including to add, query, delete and modify records and to provide some maintenance technology help;
2. Receiving and preserving the data from A/D transformation instrument that changes the simulation information from sensors into digit information, then processing data and judging results according to installed criteria, and printing out inspection results as the last operation. This whole process is online displayed on the computer screen;
3. Inquiring about and printing out statistical inspection results; and
4. The judgement criteria can be conveniently chosen and modified. The password is set up to stipulate the rights to adjust the judgement criteria.

Table 2. The Check Results of Braking Test Platform

	Zero point error	Zero point drift	Error of displayed value	
			When braking power≤4%(F.S)	When braking power >4%(F.S)
Criteria	≤0.1%(F.S)	≤0.1%(F.S)/30min	≤0.4%(F.S)	≤5%(F.S)
Tested value	0	0	0.2%	2.5%

Table 3. The Check Results of Test Platform of Axle Weight

	Zero point drift	Error of displayed value		Repeat error
		When braking power≤4%(F.S)	When braking power >4%(F.S)	
Criteria	≤0.1%(F.S)/30min	≤5%(F.S)	≤2%(F.S)	≤2%
Tested value	0	0.5%	0.2%	0.2%

Table 4. The Check Results of Test Platform of Speed

	Zero point error	Zero point drift	Error of displayed value
Criteria	≤1km/h	1km/h/30min	≤3%
Tested value	0	0	0.6%

Trial Evaluation

Trial of Test Platform

The test platform includes the braking torque test platform, axle weight test platform and speed test platform. Based on the trial, the check results of the key performance indexes are shown respectively in **Tables 2, 3** and **4.** The accuracy of braking torque is 0.1 kg · m. The accuracy of axle weight is 0.1 kg. The accuracy of driving speed is 0.01 km/

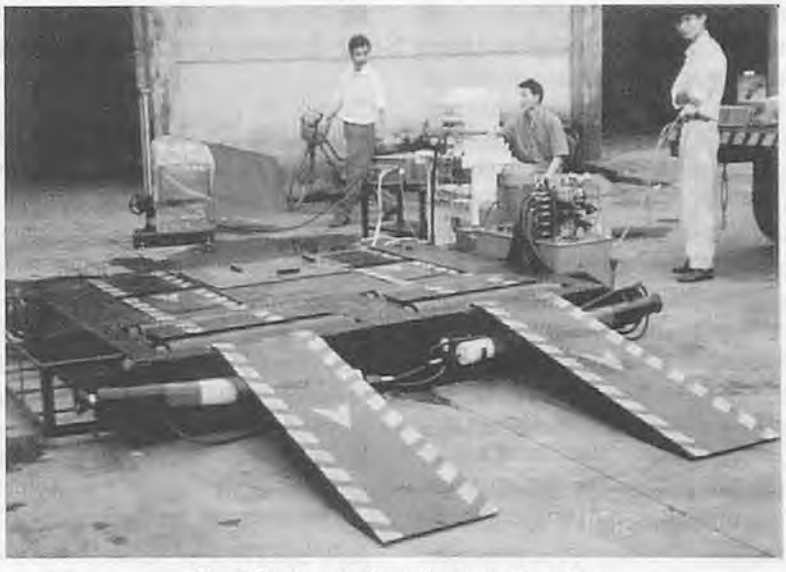


Fig. 5 Testing platform for testing tractors.

h. The time spent in inspecting a tractor is 3 minutes. More than 150 units can be inspected a day.

Mobility Check

The mobility of the equipment is evaluated by the speed and balance ability of test platform being elevated or loaded down, and the safety reliability during transport. According to the trial, the speed of test platform being elevated is 1 minute/each time, and the load down speed is 0.6 minute/each time. The maxim angle of inclination of test platform on being elevated or loaded down is less than 0.2°. The test platform is stable and reliable during transport.

Analysis on the Inspection Results and Practical Evaluation

The inspection equipment is practically applied in eight towns in Lingan county. Over 5,000 tractors have been inspected. The average inspection results were as follows: the unqualified rate was19%. Among these, the waste gas was 1.8%; the noise was 1%; the light power was 0.2%; the braking torque was 7%. The results proved that the performance related to driving safety of the tractors was bad in this region. The management department should take measures to improve the present condition.

According to the results of the practical application, the new-type equipment qualified the designing requirement. It had the advantages of easily being transported and being operated, high working reliability and low price. It was practically proved that this equipment was suitable as an inspection tool.

Conclusion

The successful design and development of mobile performance inspection equipment for tractors is involved in the complex applications of multi-technologies such as mechanism, electricity, hydraulic pressure, electronic, and computer. It is also concerned in the specialized knowledge relative to the performance inspection of tractors.

The performance inspection for automobile has been done for a long time in our country, but for tractor, it is only in the initial stage. The inspection technology and equipment for tractors need to be developed rapidly.

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The Potential of Using Solar Energy for Chick Brooding in Port Harcourt, Nigeria

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Studies on Suitability of Lower Ethanol Proofs for Alcohol – Diesel Microemulsions

by

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Abstract

The stability and homogeneity of 32 microemulsions prepared by mixing 150°, 160°, 170° and 180° proof ethanol-1-butanol-diesel in different proportions were studied. 13 microemulsions were stable. However, microemulsions with 170° and 180° proof ethanol in 1:2.5:5.5 and microemulsion with 180° proof ethanol-1-butanol-diesel in 1:2:3 ratio were more suitable for fuel use in C I engines based on the comparison of their characteristic fuel properties with diesel.

Introduction

The rising prices of petroleum fuels, dwindling oil reserves and stiff regulations on exhaust emissions have necessitated the substitution of fossil fuels with less polluting and easily available renewable fuels for use in IC engines. Among the renewable liquid fuels, alcohols have been the most popular and widely used alternative fuel in S I engines. In contrast to fossil fuels that are available in a few parts of the world, alcohols can be produced in most parts of the world from selected biomass, including agricultural residues. If the use of alcohols as engine fuel is encouraged in, then apart from saving foreign exchange by the oil importing countries, the farmers there would be able to cultivate energy crops like sugarcane, potato, sweet sorghum, etc. in a big way and fetch remunerative prices for them.

Acknowledgement

The authors are thankful to the Indian Council of Agricultural Research for funding the research project. The authors are also grateful to the Dean, College of Technology and the Director, Experiment Station, GBPUA and T, Pantnagar for providing the necessary facilities.

Review of Literature

The physical and thermodynamic characteristics of alcohols do not make them particularly suitable fuels for compression ignition engines, but they offer a means of reducing exhaust emissions of sulphur compounds, smoke, particulates and No_x. The factors requiring consideration for use of alcohols as C I engine fuel are the lower viscosity and lubricity of alcohols, which would cause excessive wear in conventional fuel injection equipment.

The commercially available ethanol grades contain between 10-20 % water. Due to the incompatibility of diesel and water, phase separation takes place in the blend. This phenomenon is characterized by the formation of two layers rendering the blend unsuitable for use as fuel. An engine adjusted to burn petroleum fuel efficiently would produce less power from alcohol if the alcohol separates from the petroleum fuel (Miller *et al)*.

Water-in-oil type of emulsions can be used in place of blend in order to increase its water tolerance. Such emulsions are formed either by adding emulsifying agents or by mechanical means such as ultrasonic agitation. Emulsions formed by agitation, however, remain emulsified only for very brief periods. A water-in-oil emulsion takes the form of either a macroemulsion or microemulsion. Macroemulsions have dispersed particles with diameters in the range of 200 to 10000 nm and are unstable, eventually separating into two phases (Brouff *et al)*.

Stable microemulsions using suitable emulsifying agents, like 1 butanol can be used to sufficiently reduce the interfacial tension between the dispersed and continuous phases in a blend using aqueous ethanol. In the case of an ethanol-1-butanol-diesel microemulsion, diesel forms the continuous phase while aqueous ethanol forms the dispersed phase. 1 butanol, like ethanol can be produced by fermentation processes and can be obtained more easily in the anhydrous state than ethanol and it is miscible with diesel fuel oil (Boruff *et al*).

In view of the above facts studies were undertaken to determine the suitability of different ethanol proofs for their use as ethanol-diesel microemulsions using 1 butanol as emulsifying agent and characteristic fuel properties of selected stable and homogeneous microemulsions to assess suitability as CI engine fuel.

Materials and Methods

Ethanol proofs of 150°, 160°, 170° and 180° were used for the preparation of ethanol-1-butanol-diesel microemulsions. The various ethanol proofs were prepared from the anhydrous ethanol (200° proof) by adding requisite amounts of distilled water to it. The microemulsions containing 150°, 160°, 170°, 180° proof of ethanol-1-butanol-diesel were prepared by adding the constituents in the ratio of 1:2:6, 1:2.5:5.5, 1.5:2:5.5, 1.5:2.5:5, 2:2:5 and 2:1.5:5.5. In addition to these ratios, the microemulsions containing 160° proof ethanol and other constituents in 1:3:5 ratio, and microemulsion having 170° and 180° proof ethanol in 1:3:5, 1.5:3:4.5 and 1.5:3.5:4 ratio were also prepared. A microemulsion with 180° proof ethanol mixed in 2:3:4 ratio was also tried. Ethanol of 190° proof was not used for the preparation of microemulsions. The purpose of selecting different ratios was to analyse the suitability of a microemulsion with lowest ethanol proof providing highest diesel replacement.

The quality of each microemulsion prepared was evaluated in terms of stability, homogeneity and percentage diesel replacement. A stable microemulsion is a clear, homogeneous and transparent solution whereas an unstable microemulsion looks turbid, non-homogeneous and opaque right since the time of formation. These characteristics of the microemulsions do not change even after keeping them for a long time.

The characteristic fuel properties such as density, relative density, kinematic viscosity, cloud and pour point and gross heat of combustion of ethanol-1-butanol-diesel microemulsions as well as of diesel, ethanol and 1 butanol were determined as per Indian Standards - IS 1448 [P: 32]: 1992, [P: 25]: 1976, [P: 103]: 1970 and [P: 6]: 1984, respectively.

Results and Discussion

Selection of Stable Microemulsions

The microemulsions prepared by using different proofs of ethanol and found to be stable and homogeneous are presented in **Table 1**. The table indicates that stable and homogenous microemulsions consisting of ethanol-1-butanol-diesel using 160° proof ethanol can be prepared when constituents are added either in the proportion of 1: 2.5 : 5.5 or 1 : 3 : 5. The replacement of diesel by microemulsions prepared as per above stated proportion is 39 and 44 percent, respectively. The 170°proof ethanol-1-butanol-diesel forms stable and homogenous microemulsions when they are added in one of the following proportions such as 1: 2 : 6, 1 : 2.5 : 5.5, 1 : 3 : 5, 1 : 2 : 3 and 1.5 : 3.5 : 4. The microemulsions prepared in above proportions can replace diesel by 33, 39, 44, 50 and 55 percent, respectively. The addition of 180° proof ethanol-1- butanol-diesel in proportions of 1: 2.5 : 5.5, 1 : 3 : 5, 1.5 : 2.5 ; 5, 1 : 2 : 3, 1.5 : 3.5 : 4 and 2 : 3 : 4 have been found to yield stable and homogeneous microemulsions. The range of diesel replacement was observed to be within 39 to 55 percent.

In order to select the stable and homogeneous microemulsions for studying the characteristic fuel properties out of those presented in **Table 1** the potential problems arising out of possible engine misfire, knock and reduction in cetane number were taken into consideration for evaluation of engine performance. Researchers in the past have reported that a microemulsion prepared from 190° proof ethanol-1-butanol-diesel when added in the ratio of 1: 2 : 6 had a cetane number of 32.9 and resulted in satisfactory engine performance (Boruff *et al*).

Table 1. Microemulsions found Stable and Homogeneous with Low Proofs of Ethanol

Microemulsion Type	Ethanol proof (°)	Proportion of fuel constituents Ethanol : 1 Butanol : Diesel			Diesel replacement (%)
160°-10/25/55	160	1	2.5	5.5	38.9
160°-10/30/50	160	1	3	5	44.4
170°-10/20/60	170	1	2	6	33.3
170°-10/25/55	170	1	2.5	5.5	38.9
170°-10/30/50	170	1	3	5	44.4
170°-15/30/45	170	1	2	3	50.0
170°-15/35/40	170	1.5	3.5	4.0	55.6
180°-10/25/55	180	1	2.5	5.5	38.9
180°-10/30/50	180	1	3.0	5.5	44.4
180°-15/25/50	180	1.5	2.5	5.0	44.4
180°-15/30/45	180	1	2	3	50.0
180°-15/35/40	180	1.5	3.5	4.0	55.6
180°-20/30/40	180	2.0	3.0	4.0	55.6

Table 2. Microemulsions Selected for Determination of Characteristic Fuel properties

Microemulsion type	Proportion of fuel types (Ethanol : 1-butanol : diesel)	Diesel replacement (%)
160° - 10/25/55	1 : 2.5 : 5.5	38.9
170° - 10/25/55	1 : 2.5 : 5.5	38.9
180° - 10/25/55	1 : 2.5 : 5.5	38.9
180° - 15/30/45	1 : 2 : 3	50.0

Table 3. Characteristic Fuel properties of Diesel, Ethanol Proofs, 1- Butanol and Microemulsions

Fuel type	Relative density at 15 ℃	API gravity	Kinematic viscosity at 38 ℃ (cS)	Gross heat of combustion (kJ/kg)	Cloud point (℃)	Pour point (℃)
Diesel	0.8291	39.2	3.32	45121.4	3	0
Ethanol proofs						
200°	0.8047	44.3	0.54	31152.8	-	-
180°	0.8284	39.3	0.64	30286.5	-	-
170°	0.8361	37.7	1.27	26959.5	-	-
160°	0.8662	31.8	1.22	24686.3	-	-
1Butanol	0.7901	47.6	2.46	40339.8	-	-
Microemulsions						
180° -15/30/45	0.8221	40.6	2.24	44940.5	10	2
180° -10/25/55	0.8262	39.7	2.27	44731.3	4	1
170° -10/25/55	0.8297	39.0	2.55	44711.5	9	5
160° -10/25/55	0.8346	37.8	2.94	44676.9	28	18

Density of distilled water at 15 ℃ = 0.9986 g/cc.

Further, an alcohol-diesel blend prepared using anhydrous ethanol had a cetane number of 30 when 40 percent alcohol by volume was added to the blend. A blend containing 50 per cent alcohol by volume had a cetane number of 25 (Wrage and Goering). Based on the above considerations, the microemulsions selected for determination of characteristic fuel properties are shown in **Table 2**.

Fuel Properties

The fuel properties such as relative density, kinematic viscosity, gross heat of combustion, and cloud and pour point of the selected fuel types were determined.

Relative Density

The relative density of diesel, different proofs of ethanol, 1 butanol and selected microemulsions are shown in **Table 3**. The table shows that the relative density of diesel was 0.8291. The relative density of diesel as reported by Gupta is 0.830 and by Goering *et al* is 0.840. The relative density of ethanol having 200°, 180°, 170° and 160° proof was observed to be 0.8047, 0.8284, 0.8361 and 0.8662, respectively. The relative density of 1 butanol was 0.7901. Workman *et al.* reported the relative density of 200°, 180° and 160° proof ethanol as 0.78, 0.81 and 0.83, respectively and that of 1 butanol as 0.81. Thus the observed relative density of diesel, ethanol of different proofs and butanol were similar to those reported in earlier studies. The table also indicates that the relative density of the four microemulsions selected was very close to that of diesel.

Kinematic Viscosity

Table 3 shows the kinematic viscosity of diesel, ethanol of different proofs, 1 butanol and the four selected microemulsions at 38Åé. The kinematic viscosity of diesel was 3.32 cS. The kinematic viscosity of diesel at 38Åé may range between 2.0 to 7.5 cS (Technical Services, Indian Oil Corporation). The kinematic viscosity of 200°, 180°, 170° and 160° proof ethanol was observed to be 0.54, 0.64, 1.27 and 1.22 cS, respectively. The higher kinematic viscosity observed for the lower proof of ethanol was due to the presence of higher water content in them. The kinematic viscosity of 1 butanol was observed to be 2.46 cS. The microemulsions 180°-15/30/45, 180°-10/25/55, 170°-10/25/55 and 160°-10/25/55 had kinematic viscosity values of 2.24, 2.27, 2.55 and 2.94 cS, respectively. These values are close to those reported by Boruff *et al.* The observed values reveal that the microemulsions selected had 11 to 32 percent lower kinematic viscosity than that of diesel.

Gross Heat of Combustion

The gross heat of combustion of different fuels is shown in **Table 3**. The table indicates that the gross heat of combustion of diesel was 10768.8 kCal /kg (45121.4 kJ/kg). The gross heat of combustion of diesel as reported by Hansen *et al.* and Ajav is 10756 kCal/kg (44960 kJ/kg) and 10441 kCal/kg (43643 kJ/kg), respectively. The gross heat of combustion of 200°, 180°, 170° and 160° ethanol proofs and 1 butanol were 31152.8, 30286.5, 26959.5, 24686.3 and 40339.8 kJ/kg, respectively, which are similar to the gross heat of combustion of 200°, 180° and 160° proof ethanol as 31531, 28625 and 25718 kJ/kg, respectively, reported by Workman *et al.* The gross heat of combustion of 1 butanol as reported by Boruff *et al.* was 36000 kJ/kg.

The gross heat of combustion of 180°-15/30/45, 180°-10/25/55, 170°-10/25/55 and 160°-10/25/55 type microemulsions was 44940.5, 44731.3, 44711.5 and 44676.9 kJ/kg, respectively. The observed gross heat of combustion of the microemulsions was only 0.4 to 0.98 percent less than that of diesel. Since, the selected microemulsions have their gross heat of combustion very close to that of diesel, therefore, such microemulsions can be used as substitute for diesel in CI engines.

Cloud and Pour Point

The cloud and pour point of diesel and ethanol-1-butanol-diesel microemulsions is shown in **Table 3**. The table indicates that the cloud and pour point of diesel was 3Åé and 0Åé, respectively. The table also reveals that the cloud point of 170°-10/25/55, 180°-10/25/55 and 180°-15/30/45 microemulsion type was 9.0, 4.0 and 10.0℃, respectively. The microemulsion 170°-10/25/55 had a higher value of cloud point than 180°-10/25/55 (both replacing 39 per cent diesel) because the former contained 5 per cent more water. The microemulsion 160°-10/25/55 showed phase separation characteristics when cooled to 28℃. It is clear from the table that the pour points of 180°-10/25/55 and 180°-15/30/45 are close to each other. The pour point of 170°-10/25/55 is higher because of higher water content.

Preliminary engine tests were also carried out on the selected microemulsions wherein the engine was run on selected loads to observe the occurrence of misfire or audible knock. It was noticed that the engine operation was satisfactory on the above fuel types.

Conclusion

The microemulsions prepared using 170° and 180° proof ethanol-1-butanol-diesel in 1:2.5:5.5 ratio replacing 39 percent diesel were stable and homogeneous. A microemulsion having 180° proof ethanol-1-butanol-diesel in 1:2:3 ratio was also stable. This microemulsion can replace 50 percent diesel. The relative density, kinematic viscosity and gross heat of combustion of these microemulsions were close to diesel. The operation of a constant speed CI engine satisfactory on these microemulsions.

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Impact of Farm Mechanization on Employment and Entrepreneurship

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Abstract

The results of the study show that as a consequence of increasing use of farm machines and equipment in some of the farm operations for selected crops, the employment opportunities has been reduced on the farmers' field. In study area in Haryana, 733.3 (51.19%), 335.25 (38.58%), 132.26 (15.95%) and 148.46(22.24%) man-hours of employment/ha has been reduced in wheat, rapeseed/ mustard, pearl millet and sorghum, respectively, as a consequence of the use of mechanized means. In the case of Rajasthan, this reduction in man-hours of employment per ha was observed at 707.18 (47.60%) in wheat, 293.69 (34.07%) in rapeseed/mustard, 109.98 (13.90%) in pearl millet and 139.57 (20.70%) in sorghum crop.

On further analysis of data, it was found that reduction in man-hours of employment/ha in the four crops together at the time of study was 337.33 (35.52%) in Haryana and 312.64 (32.92%) in Rajasthan. If all farmers were to take mechanized means in land preparation, sowing and fertilizer application and threshing of all four crops, the possibility of reduction in labour employment in the four crops together would be 472.86 (42.19%) and 480.28 (43.20%) man-hours/ha in Haryana and Rajasthan, respectively. The difference in actual reduction at present and possibility under fully mechanized condition for above activities is mere 6.67 percent and 10.28 percent in Haryana and Rajasthan, respectively, which is likely to happen sooner or later in the future.

The majority of the farmers in Haryana (73.91%) and Rajasthan (61.68%) were of the view that farm mechanization had increased overall " on and off" farm employment opportunities. According to these farmers a reduction in labour employment the diversification in terms of crops grown and cropping intensity and enterprises that have emerged in the wake of mechanization has actually increased employment opportunity. Majority of the farmers in Haryana (52.38%) and Rajasthan (50.30%) reported that all adult members of their families were not having adequate employment on their own farms.

The enterprise developed as a direct or indirect impact of farm mechanization were: electric pumpset repairing centres, farm and non-farm machinaries repairing centres, tractor custom hiring services, business in second-hand farm machineries, poultry rearing, dairying/milk supplying, transportation by non-farm machines and transportation by bullock/camel carts. The total number of such kinds of enterprises was higher in Haryana (204) than in Rajasthan (131) with a density of 12.96 and 8.91 per thousand of farming population, respectively. The annual man-days of employment generated by these enterprises together were 40,150 in the study area in Rajasthan. Thus the employment generation in these enterprises was 18,371 man-days higher in the study area in Haryana in Rajasthan.

Introduction

Modernization in agriculture being intricately linked to farm mechanization has resulted in the adoption of farm machineries such as tractors, power tillers, combine harvester, irrigation pump sets and threshers. For higher growth rate in agricultural production and productivity, farm mechanization is indispensable. The policy on mechanization under the ninth five-year plan emphasizes increased use of farm machines assuring that farm labour does not, in the process, get laid off. The impact of farm mechanization on labour employment remains a question of debate. It is argued that farm mechanization is oriented to intensification of agriculture and to break the labour peak arising from development in technology in dynamic context. There is a common belief that farm mechanization has negative impact on the employment of farm labour and is suitable only for big farms. The issue of farm labour employment vis-à-vis mechanized versus non-mechanized farms is quite simple and obvious.

The information and knowledge about the various enterprises associated with farm mechanization is scanty and rare.

The present study was conducted to assess the employment and entrepreneurial implications of farm mechanization.

Methodology

The study was conducted in the Pataudi block of Gurgaon district, Haryana and Bandikui block of Dausa District, Rajasthan. Four villages each from the two blocks using purposive random method of sampling were selected.

From the villages in Pataudi block, 30 farmers who own tractors and other 30 who own neither tractor nor bullock/camel were selected randomly and all the available 24 farmers who own bullock/camel were included as sample of the study. From the four villages of Bandikui block, 30 bullock/camel owning and 30 neither tractor nor bullock/camel owning farmers were selected randomly while all the available 23 tractor owning farmers were included purposively. Thus in all, a total of 84 farmers were selected from Pataudi block of Gurgaon district (Haryana) and 83 farmers from Bandikui block of Dausa district (Rajasthan) made a total of 167 respondents of the study.

Data collection and analysis

The data were collected by participatory interview method using specially developed semi-structured interview schedule.

To study the change in labour employment, four major crops commonly grown in Haryana and Rajasthan were identified: wheat, rapeseed/mustard, pearl millet and sorghum.

To gather information on enterprises and entrepreneurship developed due to farm mechanization, data was collected through participatory group meetings with village elders and youth in each of the eight villages.

Results and Discussion

Wheat

The land preparation in wheat crop was largely carried out by using tractors. The data in Haryana were 106.27 (73.04%) man-hours/ha which were reduced in " land preparation activities" due to mechanization. Rajasthan being comparatively less mechanized, recorded a lower reduction of 56.84 (46.32%) man-hours for the same. In land preparation, the reduction was 49.43 man-hours/ha, i.e., 26.72% higher in Haryana than Rajasthan (**Table 1**).

In sowing and fertilizer application activities using mechanized means, the farmers reported a reduction of 58.22 (90.96%) and 33.54 (55.90%) man-hours/ha in of Haryana and Rajasthan, respectively. In sowing and fertilizer application, the reduction in man-hours/ha was 24.68, i.e. 35.06 percent less in Rajasthan than Haryana. This variability is mainly because in Rajasthan still 42.1 percent farmers were using non-mechanized means (bullock/camel) for the purpose of sowing and fertilizer application in wheat crop while in Haryana only 6.0 percent farmers using non-mechanized means for this purpose.

In the case of irrigation in wheat crop, 423.0 (72.93%) man-hours/ha in Haryana and 463.0 (73.50%) man-hours/ha in Rajasthan were reported to have reduced after farm mechanization, especially after the introduction of electric motors/diesel engines for the purpose of irrigation.

In the case of threshing of wheat, the extent of reduction in man-hours/ha in both Haryana and Rajasthan was more or less similar, i.e., 160.0 (84.32%) and 153.80 (83.59%), respectively, after the adoption of tractor/electric threshers. Similar findings were reported by Arya (1998) and Singh and Singh (1980).

The overall reduction of labour input in wheat crop as a whole in Haryana was 733.3 (51.19%) and in Rajasthan 707.18 (47.60%) man-hours/ha.

Rapeseed/Mustard

Data in **Table 2** show that in land preparation for rapeseed/mustard, 151.42 man-hours/ha were reduced in Haryana accounting for 77.25 percent reduction while in Rajast-

Table 1. Change in Labour Employment in Wheat Crop due to Farm Mechanization

Operation	Haryana				Rajasthan			
	Average man-hours employed/ha				Average man-hours employed/ha			
	AM (N=84)	BM (N=84)	Δ	%Δ	AM (N=83)	BM (N=83)	Δ	%Δ
Land preparation	39.23	145.50	-106.27	-73.04	65.86	122.70	-56.84	-46.32
Sowing and fertilizer application	5.78	64.00	-58.22	-90.96	26.46	60.00	-33.54	-55.90
Irrigation	157.00	580.00*	-423.00	-72.93	166.0	629.00*	-463.00	-73.60
Interculture operations	205.00**	205.00**	0.00	0.00	240.00**	240.00**	0.00	0.00
Plant protection	14.39**	0.00	14.39	NP	0.00	0.00	0.00	0.00
Harvesting	248.00**	248.00**	0.00	0.00	250.00**	250.00**	0.00	0.00
Threshing	29.80	190*	-160.00	-84.32	30.20	184.00*	-153.80	-83.59
Total	699.20	1432.50	733.30	-51.19	778.52	1485.70	-707.18	-47.60

AM = after mechanization.
BM = before mechanization.
Δ = Change in man-hours over pre-mechanization.
%Δ = Percent change in man-hours over pre-mechanization.
* = Data reported on recall basis.
** = Operations done manually only.
NP = Not possible.

han this reduction was comparatively lower, i.e., 82.15 (48.04%) man-hours/ha as a consequence of adoption of mechanical means. The wide variability between the two regions in terms of reduction of labour employment for land preparation in rapeseed/mustard was due to the large percentage of farmers (38.5%) of Rajasthan still using non-mechanized means, i.e., bullock/camels for land preparation.

In the case of sowing and fertilizer application in rapeseed/mustard crop, there was a reduction of 23.32 (86.38%) and 14.37 (62.49%) man-hours/ha in Haryana and Rajasthan, respectively, due to the use of tractor only or tractor operated seed drill/seed-cum-fertilizer drills. Balisther and Singh (1983) reported that labour absorption/ha of cultivated area was the lowest on mechanized farms in preparatory tillage, sowing/planting and threshing in almost all crops.

In Rajasthan, the reduction in man-hours/ha in irrigation was 98.36 (72.31%) while in Haryana it was 90.50 (55.69%).

In the case of threshing of rapeseed/mustard crop, all farmers in both states adopted mechanized means. However, the reduction in man-hours employment for this activity was 125.0 (82.24%) man-hours/ha in Haryana, which were slightly higher than 123.0 (77.85%) man-hours/ha in Rajasthan. The higher reduction in man-hours/ha in Haryana was reportedly due to the fact that the farmers recently made use of mechanical threshing means like "Harmpa" which was comparatively with higher capacity to thresh the crop in less time and labour hours than the normal thresher.

For interculture operations and harvesting activities no differences was observed in man-hours employed because these two operations were done manually both in pre- and post-mechanization period.

Overall, reduction in man-hours/ha in rapeseed/mustard crop was higher in Haryana 335.25 (38.58%) than in Rajasthan 293.69 (34.70%) because of comparatively more farmers using mechanical means in different operations for this crop in Haryana.

Table 2. Change in Labour Employment in *Rapeseed/mustard* Crop due to Farm Mechanization

Operation	Haryana: Average man-hours employed/ha				Rajasthan: Average man-hours employed/ha			
	AM (N=84)	BM (N=84)	Δ	%Δ	AM (N=83)	BM (N=83)	Δ	%Δ
Land preparation	44.58	196.00	-151.42	-77.25	88.85	171.00	-82.15	-48.04
Sowing and fertilizer application	3.68	27.00	-23.32	-86.38	8.63	23.00	-14.37	-62.49
Irrigation	72.00	162.50*	-90.50	-55.69	87.64	186.00*	-98.36	-72.31
Interculture operations	127.27**	127.57**	0.00	0.00	88.55**	88.55**	0.00	0.00
Plant protection	55.29	0.00	55.29	NP	24.19	0.00	24.19	NP
Harvesting	204.00**	204.00**	0.00	0.00	220.00**	220.00**	0.00	0.00
Threshing	27.00	152.00**	-125.00	-82.24	35.00	158.00*	-123.00	-77.85
Total	533.82	869.07	-335.25	-38.58	552.86	846.55	-293.69	-34.70

AM = after mechanization.
BM = before mechanization.
Δ = Change in man-hours over pre-mechanization.
%Δ = Percent change in man-hours over pre-mechanization.
* = Data reported on recall basis.
** = Operations done manually only.
NP = Not possible.

Table 3. Change in Labour Employment in Pearl Millet Crop due to Farm Mechanization

Operation	Haryana: Average man-hours employed/ha				Rajasthan: Average man-hours employed/ha			
	AM (N=84)	BM (N=84)	Δ	%Δ	AM (N=83)	BM (N=83)	Δ	%Δ
Land preparation	31.09	72.00	-40.91	-56.82	47.70	61.00	-13.30	-21.81
Sowing and fertilizer application	5.11	44.19	-39.08	-88.44	11.61	38.46	-26.84	-69.80
Irrigation	73.50	0.00	73.50	NP	57.69	0.00	57.69	NP
Interculture operations	288.00**	288.00**	0.00	0.00	260.00**	260.00**	0.00	0.00
Plant protection	6.15	0.00	6.15	NP	0.00	0.00	0.00	0.00
Harvesting	265.06**	265.06**	0.00	0.00	270.00**	270.00**	0.00	0.00
Threshing	28.09	160.00*	-131.91	-82.44	37.48	162.00*	-124.52	-76.86
Total	697.00	829.25	-132.26	-15.95	681.48	791.46	-109.98	-13.90

AM = after mechanization.
BM = before mechanization.
Δ = Change in man-hours over pre-mechanization.
%Δ = Percent change in man-hours over pre-mechanization.
* = Data reported on recall basis.
** = Operations done manually only.
NP = Not possible.

Pearl millet (Bajra)

The data in **Table 3** show that in land preparation, 40.91 (56.28%) and 13.30 (21.81%) man-hours/ha were reduced in Haryana and Rajasthan, respectively, due to the use of mechanical means (tractors). The reduction in man-hours employment/ha in Bajra crop was considerably lower than for wheat and rapeseed/mustard crop in both study areas.

The reduction in labour employment in Bajra crop was 27.61 man-hours/ha (35.01%) higher in Haryana than in Rajasthan due to a larger percentage of farmers (94%) using tractors for the same purpose.

In sowing and fertilizer application activities too, a considerably reduction in man-hours was observed in Haryana (39.08 man-hours) and Rajasthan (26.84 man-hours). Since, 27.8 percent of the farmers in Rajasthan still use their bullocks/camels for sowing and fertilizer application activities in bajra crop as contrast to a mere 7 percent in Haryana, hence the opportunity of man-hours employment per hectare in this operation was higher in Rajasthan than in Haryana.

The threshing of bajra was increasingly being carried out by mechanized means. As a result, the reduction in man-hours/ha was 131.91 (82.44%) in Haryana and 124.52 (76.86%) in Rajasthan. The reduction in man-hours/ha was lower in Rajasthan due to the fact that 9.70 percent farmers used their bullocks for threshing. This method of threshing is time and labour consuming. Sharma (1985) also reported that employment was reduced on tractor operated farms.

The overall reduction in average man-hours employment in bajra crop, in Haryana was 132.26 (15.95%) and in Rajasthan, 1009.98 (13.90%). Reduction in man-hours employment in the latter state was comparatively lower than the former because a few farmers in Rajasthan continue to use traditional means for various farm operations.

Sorghum (Jowar)

In the case of sorghum (**Table 4**) in Haryana, the reduction in man-hours employment/ha in land preparation was 34.60 (58.38%) compared with 22.56 (39.58%) in Rajasthan as more farmers of Haryana used mechanized means in land preparation.

In sowing and fertilizer application for this crop, 34.17 (87.99%) and 24.94 (76.74%) man-hours/ha decreased in Haryana and Rajasthan, respectively, as a consequence of farm mechanization.

In threshing operation for jowar maximum man-hours/ha were reduced in both Haryana and Rajasthan. This reduction was to the extent of 141.10 (85.0%) man-hours/ha in Haryana and 132.24 (78.96%) in Rajasthan. Sharma and Sirohi (1980) supported these findings that a negative elasticity existed between labour employment and farm mechanization of the order of 0.05 percent indicating a decrease in labour employment due to one percent increase in farm mechanization.

The lower reduction in man-hours employment/ha in Rajasthan was due to the fact that in Rajasthan 8.5 percent farmers use bullocks for threshing jowar wherein grains are separated from the ears by trampling method which is more time consuming and labour intensive.

The overall reduction in man-hours employment in Haryana was 148.46 (22.24%) compared with Rajasthan of 139.57 (20.70%) man-hours/ha.

The overall reduction in labour employment had occurred in both the study areas: 337.33 man-hours/ha in Haryana and 312.64 man-hours/ha in Rajasthan.

If all farmers used mechanized means in land preparation, sowing and fertilizer application, and threshing activities, the possibility of reduction in labour employment in the four crops would be 472.86 (42.19%) and 480.28 (43.20%) man-hours of employment/ha in Haryana and Rajasthan, respectively. The difference in actual reduction at present and possibility under fully mechanized condition for above activities is 6.67 percent and 10.28 percent in Haryana and Rajasthan, respectively, which is likely to happen sooner or later in the future.

Table 4. Change in Labour Employment in Sorghum Crop due to Farm Mechanization

Operation	Haryana				Rajasthan			
	Average man-hours employed/ha				Average man-hours employed/ha			
	AM (N=84)	BM (N=84)	Δ	%Δ	AM (N=83)	BM (N=83)	Δ	%Δ
Land preparation	30.22	64.82	-34.60	-53.38	34.44	57.00	-22.56	-39.58
Sowing and fertilizer application	4.66	38.83	-34.17	-87.99	7.56	32.50	-24.94	-76.74
Irrigation	53.55	0.00	53.55	NP	42.17	0.00	42.17	NP
Interculture operations	131.87**	131.87**	0.00	0.00	143.59**	143.59**	0.00	0.00
Plant protection	7.86	0.00	7.86	0.00	0.00	0.00	0.00	0.00
Harvesting	266.00**	266.00**	0.00	NP	271.00**	271.00**	0.00	0.00
Threshing	24.90	166.00*	-141.10	-85.00	35.76	170.00*	-134.24	-78.96
Total	519.06	667.52	-148.46	-22.24	534.52	674.09	-139.57	-20.70

AM = after mechanization.
BM = before mechanization.
Δ = Change in man-hours over pre-mechanization.
%Δ = Percent change in man-hours over pre-mechanization.
* = Data reported on recall basis.
** = Operations done manually only.
NP = Not possible.

Implication of Farm Mechanization on Employment as Perceived by Farmers

Increase/Decrease in Employment in in and off Farm Activities

The data in **Table 5** show that 80.0 percent of TO, 58.30 percent of BCO and 63.30 percent of NTNBCO farmers of Haryana were of the opinion that due to farm mechanization there has been an increase in overall on and off farm employment. On the whole 69.00 percent of Haryana farmers were of the view that farm mechanization had increased on and off farm employment.

In Rajasthan, 50.0 percent TO, 46.67 percent BOC and 55.42 percent NTNBCO farmers perceived that farm mechanization increased over all on and off farm employment. Of all the farmers of Rajasthan 55.42 percent were of the view that farm mechanization had increased the over all on and off farm employment while 44.58 percent farmers believe that farm mechani-

Table 5. Comparative Percentage in Expressing Opinions/Perceptions

Implications	Farmers' opinion or perception	Haryana TO (N=30)	Haryana BCO (N=24)	Haryana NTNBCO (N=30)	Haryana Total (N=84)	Rajasthan TO (N=23)	Rajasthan BCO (N=30)	Rajasthan NTNBCO (N=30)	Rajasthan Total (N=83)	Overall total (Har.+Raj.0 All three categories of farmers (N=167)
Farm mechanization increased/decreased	Increased	24 (80.00)	14 (58.30)	19 (63.30)	57(69.00)	17 (73.91)	15 (50.00)	14(46.67)	46 (55.42)	103 (61.68)
overall (on and off) farm employment opportunity	Decreased	6 (20.00)	10 (41.70)	11 (36.70)	27 (31.00)	6 (26.09)	15 50.00)	16 (53.33)	37 (44.58)	64 (38.32)
Farm mechanization has displaced labour force	Yes	18 (60.00)	18 (75.00)	23 (76.60)	59 (70.20)	17 (73.91)	21 (70.00)	23 (76.67)	61 (73.49)	120 (71.86)
from farming	No	12 (40.00)	6 (25.00)	7 (23.40)	25 (29.80)	6 (26.09)	9 (30.00)	7 (23.33)	22 (26.51)	47 (28.14)
All adult members of your family get ade-	Yes	13 (43.33)	15 (62.50)	12 (40.00)	40 (47.62)	9 (39.13)	20 (66.67)	14 (46.67)	43 (51.81)	83 (49.70)
quate employment on your own farm	No	17 (56.67)	9 (37.50)	18 (60.00)	44 (52.38)	14 (60.87)	10 (53.33)	16 (53.33)	40 (48.19)	84(50.30)

TO = Tractor owning farmers.
BCO = Bullock/camel owning farmers.
NTNBCO = Neither tractor nor bullock/camel owning farmers.

zation had infact contributed to reduction in over all on and off farm employment.

Taking all the farmers from both states a large majority (61.68%) were of the opinion that farm mechanization had increased over all on and off farm employment.

Labour Employment in Farming Activities Only

The data in **Table 5** show 60.00 percent TO, 75.00 percent BCO and 76.00 percent NTNBCO farmers in Haryana believed that farm mechanization had displaced labour force from farming operations.

In Haryana, 70.20 percent of the farmers were of the opinion that farm mechanization had displaced labour force from farming while 29.80 percent did not believe so.

In Rajasthan, 73.49 percent of the farmers generally believed that farm mechanization displaced labour from farming.

A large majority comprising 71.86 percent of total sample in both study areas were of the view that farm mechanization had played an important role in displacement of labour force from farming while only 28.14 percent farmers believed otherwise.

Adequacy of Employment for All Adult Family Members on Their Own Farms

It was interesting to note that over 60 percent of the farmers in both study areas reported that all their adult family members were fully employed in their own farms. However, majority of the farmers who owned tractors and those who owned neither tractors nor farm animals expressed that they were not getting full employment in their own farms for all adult members of their family.

Table 6. Extent of Entrepreneurship due to Direct/indirect Impact of Farm Mechanization

Enterprise	Haryana (pooled data of four villages) Number of enterprises	Haryana Enterprises per 1000 of farming population	Rajasthan (pooled data of four villages) Number of enterprises	Rajasthan Enterprises per 1000 of farming population
Direct impact				
Electric pumpset repairing centres	11	0.70	9	0.61
Farm and non-farm machinaries repairing centres	05	0.32	4	0.27
Ploughing and sowing	28	1.78	23	1.56
Threshing	22	1.40	16	1.09
Transportation	24	1.53	22	1.50
Business in new/second hand farm machinaries	08	0.51	5	0.34
Total (a)	98	6.23	79	5.37
Indirect impact				
Poultry rearing	15	0.95	5	0.34
Dairying/milk supplying	20	1.27	14	0.95
Food processing (flour/dal/oil mills)	20	1.27	14	0.95
Transportation services by jeep, jhonga, jugar	38	2.41	15	1.02
Transportation services by bullock / camel cart	13	083	11	0.75
Total (b)	106	6.73	52	3.54
Overall total (a+b)	204	12.96	131	8.91

Entrepreneurial Implications of Farm Mechanization

In the present study the entrepreneur is operationally defined as the farmer who has created new economic activity (enterprise) by using his spare time and resources like farm machines, animals, etc., to add extra income to his own total agricultural income.

For purposes of the present study all enterprises related to agriculture that had emerged as a direct consequence of mechanization like electric pumpset repairing centres, farm and non-farm machinery repairing centres, business in new/ second hand farm machines, tractor custom hiring services or as an indirect impact like poultry rearing, dairying, food processing, transportation services by jeep, jhonga, jugar/bullock/camel carts were included in the analysis of the extent of entrepreneurship generated within the farm families.

Enterprise Initiated as Direct Impact of Farm Mechanization

In four study villages in Pataudi block of Gurgaon (Haryana), the enterprises developed as a direct consequence of farm mechanization were: 11 electric pumpset repairing centres, 5 farm and non-farm machineries repairing centres, 74 tractor custom hiring services enterprises and 8 business enterprises in new/second hand farm machineries totaling 98 (**Table 6**). All enterprises (excluding business in new/second hand machineries) generated a total of 5,867 man-days of employment annually accounting 372.86 man-days of employment per year per thousand of farming population of the study in Haryana. The highest man-days of employment (2,528) were generated by tractor custom hiring services followed by farm and non-farm machineries repairing centres (**Table 7**).

Lewis (1996) supported these findings that the failure of cooperative institutional arrangements for farm mechanization stimulated local rural entrepreneurs to establish their own custom hiring ploughing and other entrepreneurial service delivery systems through farm machineries.

Almost a similar picture emerged in the study areas in Rajasthan (**Table 7**).

Enterprises Initiated as a Indirect Impact of Farm Mechanization

Poultry rearing, dairying/milk supplying, food processing, transportation services by either bullock/ camel carts or mechanized vehicles in both study areas were initiated as a indirect consequence of farm mechanization.

Kayembeh (1982) also reported that farm mechanization eases labour for deviation to other activities which are either wholesome leisure thereby increasing productive activities such as cottage industries or other farming enterprises like poultry and livestock raising. Such enterprises in Haryana were 106 and 52 in Rajasthan with total man-days of employment generated annually.

Conclusion

The reduction in man-hour employment in four selected crops viz., wheat, rapeseed/mustard, pearl millet and sorghum was higher in Haryana study areas of than in Rajasthan. Diversification in employment was a consequence of farm mechanization. The entrepreneurial activities were initiated more in Haryana than in Rajasthan due to the farm mechanization.

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Table 7. Employment Generation in Enterprises due to Direct/Indirect Impact of Farm Mechanization

Enterprise	Haryana (Pooled data of four villages)				Rajasthan (Pooled data of four villages)			
	Number of men employed (a)	Average man-days/year (b)	Total number of man-days of employment/year (a×b)	Avg. man-days generated per 1000 of farming population per year	Number of men employed (c)	Average man-days/year(d)	Total number of man-days of employment/year (c×d)	Avg. man-days generated per 1000 of farming population per year
i. Direct impact								
Electric pump set repair centres	11	79	869	55.23	9	72	648	44.05
Farm and non-farm machineries repair and services centres	10	240	2400	152.53	8	232	1856	126.18
Ploughing and sowing	28	32	896	56.94	23	44	1012	68.80
Threshing	22	25	550	34.95	16	32	512	34.81
Transportation	24	48	1152	73.21	22	59	1298	88.25
Total (i)			5867	372.86			5326	362.09
ii. Indirect impact								
Poultry rearing	23	365	8395	533.52	8	365	2920	198.52
Dairying/milk supplying	40	365	14600	927.87	18	365	6570	446.67
Food processing (flour/ dal/oil mills)	20	273	5460	347.95	14	260	3640	248.15
Mechanical transportation service	38	139	5282	335.68	15	179	2685	182.54
Animal transportation services	13	42	546	34.70	11	58	638	43.37
Total (ii)			34283	2178.77			16453	1118.57

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Agricultural Mechanization in Hills of Himachal Pradesh – a Case Study

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Abstract

The agricultural mechanization status in Himachal Pradesh shows that the farmers are still utilizing the traditional farm tools and implements in most of the farm operations. The power availability is quite low, i.e., 0.51 kW/ha of which 0.42 kW/ha is from animate power. The machinery availability per thousand hectare is also very low, i.e., less than 5 except animal drawn plough, threshers and sprayers. From the survey, it is also clear that the animate power is dominating in all the agricultural operations as performed in hill farming. Most of the farm operations were carried out by farm women with traditional tools except ploughing, puddling and planking. The average annual use of animal power is 81.3% and 87.7 % in Kangra and Mandi for mainly under land preparation (ploughing, puddling and planking), respectively. The power tiller was mostly used at own farm and farmers pointed out non-availability of suitable matching implements with the power tiller. The tractor power was utilized about 60 % mostly for transportation because of unique topographical features and small-sized fields. As evident from this study, the users of agricultural tools and machines are working under stress and need improved tools and machines in most of the farm operations for increasing the productivity of hill agriculture. For the successful implementation of farm mechanization in rural areas it requires an effort by policy makers, institutions and extension agents to introduce suitable technology at farmers' fields.

Introduction

In Himachal Pradesh, the main occupation of the people is agriculture because it provides direct employment to about 72 % of total main workers of the state. These workers in the farm are still using conventional method of farming with age-old primitive farm tools and implements (Vatsa et.al., 1999). The productivity on these farms is not very encouraging due to the low level of mechanization. At present, power availability per hectare is about 0.5 kW/ha which is very low for timely sowing of crops in particularly rainfed condition which occupies 80 % of the net cultivable area of the state. On the other hand, neighbouring states farmers are using more than 3 kW/ha power and modern techniques (Srivastava, 1999) for enhancing production. Studies on farm mechanization have shown that the use of adequate power and improved implements results in timely operations, increased cropping intensity and better quality of field work in terms of higher crop production (Calilung and Stickney, 1989; Singh, 1984). Recently, the government of India has given top priority for doubling food production for the next 10 years in which hill agriculture is identified as one of the areas where productivity can be increased by the introduction of mechanization. Although, there has been a general increase in the average yield during the preceding years, the increasing yield is not expected to meet even the food grain requirements of the increasing population.

In the era of modernization, there is a great need to mechanize hill farming with suitable power source and implements for attracting young workers who are leaving the agriculture and searching jobs in overcrowded cities for better standard of living. Realising the fact that before introducing modern power source and implements in hill agriculture there is a need to assess the farmers' actual need particularly on power – machine use for enhancing the productivity. This paper will also help researchers and government planners for making long-term policies on the mechanization for overall development of hill farmers.

Aims of Study

The study aimed to identify the farmers' needs for power source, farm tools, implements and machines. Specifically, the aims of the study were:

1. To determine the status of power

source and machines used in various agricultural operations;
2. To determine the implements and machinery use pattern by the farmers; and
3. To suggest appropriate strategies for improving farm mechanization.

An Overview of Hill Agricultural Mechanization

Himachal Pradesh is located on a sloping terrain of the great Himalayas, with snow clad mountains, rolling hills and valleys. The elevation of the state widely ranges from 350 m to 6975 m above mean sea level. On account of the wide variations in altitude and topography, the state has broadly been divided into four zones, i.e., low hills, mid hills, high hills and cold and dry zone. The land under cultivation is 10 % of geographical area and about 80 % of cropped area is rainfed. The major crops are maize-wheat and paddy-wheat. The average yield in the state is 1620 kg/ha for wheat, 1390 kg/ha for rice and 2020 kg/ha for maize (Anonymous, 1998).

Agriculture in Himachal Pradesh is totally dependent upon animate power (Vatsa, et. al. 1996) because it involves a large working population of the state. The trend of farm power availability from various sources is shown in **Table 1**. It is clear from table that the total numbers of animals are 0.75 million while other mechanical power source such as tractor is much less. The power availability in 1977 was 0.38 kW/ha and increased up to 0.51 kW/ha in 1997, which is still quite low for timely farm operations. For increasing the production, there is a need for increased farm power up to 2.0 kW/ha (Srivastava, 1999). It is also clear from the table that the total contribution of animate power was 94.8 % in 1977, whereas it was 82.4 % in 1997. On the other hand, inanimate power is increasing from 5.12 to 17.60 % for the same period, which is still a slow pace.

Farm machinery population per 1000 ha cropped area is shown in **Table 2** showing that the most common implement is animal drawn plough numbering more than 0.7 million even as the number is decreasing. Farmers are now interested in mechanical power source with matching implements for ploughing operations also. Other implements used by the hill farmers are sprayers and threshers. The tractor and power tillers are replacing animal power in spite of terraced fields in particular, for land preparation in upland condition. The sales of mechanical power assessed for the year 1998-99 in the state were 499 tractors and 19 power tillers. In addition, agriculture development started after opening of two universities in 1980 to carry out research in agriculture but no major work on farm mechanization especially, farm power and machines has been done. For farm mechanization, the infrastructure and manpower available with organizations working in agricultural development is also negligible.

Methodology

Two districts in Himachal Pradesh, namely; Kangra and Mandi, were selected as the study areas. In selecting the study areas, the agro-ecological zones such as low hills and mid hills covering about 80% of the total cropped area of the state were duly considered (**Fig. 1**). The target groups in the study were the farmers using agricultural implements. About 120 farm households were surveyed in which major *tehsils* in both districts were studied. A structured questionnaire was

Table 1. Availability of Farm Power from Various Sources, Himachal Pradesh

Power source	1977			1982			1987			1992			1997		
	Number (Lakhs)	Total power (Lakhs) kW	Available power kW/ha	Number (Lakhs)	Total power (Lakhs) kW	Available power kW/ha	Number (Lakhs)	Total power (Lakhs) kW	Available power kW/ha	Number (Lakhs)	Total power (Lakhs) kW	Available power kW/ha	Number (Lakhs)	Total power (Lakhs) kW	Available power kW/ha
Human	16.39	1.22	0.13	20.60	1.54	0.16	23.60	1.76	0.18	26.10	1.94	0.20	28.5	2.13	0.22
Animals	8.15	2.12	0.23	7.45	1.94	0.20	8.51	2.21	0.22	7.80	2.03	0.21	7.53	1.96	0.20
Power tillers	-	-	-	-	-	-	-	-	-	0.0002	0.0001	NG	0.0003	0.0002	NG
Tractors	0.005	0.12	0.012	0.009	0.21	0.022	0.013	0.30	0.03	0.022	0.49	0.050	0.035	0.78	0.079
Diesel engine	0.010	0.037	0.004	0.012	0.043	0.005	0.024	0.088	0.009	0.013	0.046	0.005	0.012	0.043	0.005
Electric motor	0.006	0.023	0.002	0.006	0.023	0.002	0.009	0.035	0.004	0.012	0.045	0.005	0.013	0.050	0.005
Total		3.52	0.378		3.75	0.389		4.39	0.443		4.55	0.470		4.96	0.509
Net cropped area, lakh ha		9.29			9.46			9.73			9.72			9.80	
Contribution of animate power, %		94.88			92.70			90.37			87.20			82.40	
Share of inanimate power, %		5.12			7.30			9.63			12.80			17.60	

Note: NG- Negligible.

used in interviewing the farm households. Some inquiries were also obtained from the government, semi-government and small manufacturers engaged in farm equipment for more reliable information. The information received from various sources was analysed with respect to percentage of power source, machinery available, annual use of power source and gender participation for various farm operations.

Table 2. Farm Machinery Population and Number of Machines per 1000 ha of Cropped Area.

Type of equipment/ machinery	Population			Machines/1000 ha		
	1987	1992	1997	1987	1992	1997
Tractor	1319	2189	3466	1.35	2.25	3.54
Power tiller	-	12	25	-	0.012	0.025
Diesel engine	2358	1299	1150	2.42	1.33	1.17
Electric motor	934	1222	1346	0.96	1.26	1.37
Tractor drawn implements						
1. Cultivator	1162	2017	3211	1.19	2.07	3.27
2. Trailer	1306	2124	3385	1.34	2.18	3.45
Animal drawn implements						
1. Plough	799207	710349	689562	819.8	730.8	703.6
2. Bullock cart	4722	1128	532	4.84	1.16	0.54
Sprayers	11607	10525	11815	11.9	10.8	12.05
Threshers	8847	10692	12695	9.07	11.00	12.95

Findings and Discussions

Of the households surveyed, 32.1% were marginal in farm group size; 30.2 %, small; 20.1 %, medium; and 17.6 %, large. Maize, paddy and wheat were the major crops grown in both districts. The cropping intensity was 176 % in Kangra and 174 % in Mandi, which was more or less represented the average cropping intensity of 170 % in the state.

Table 3 shows the power source availability by different farm groups in both districts. The major farm power source utilized by all the farm groups is animals (bullocks). The small and marginal farmers totally depend on animal power because the tractor power was available for this farm group. The farmers did not have any power source for agricultural operations but depended on hiring of bullocks and tractors. Similarly, the number of machines available by different farm groups shows that the farmers were dependent mainly on bullock drawn plough and planker for tillage operation as they kept more than one plough per farm household (**Table 4**). The tractor-drawn cultivator, disc harrow, trailer were used by the medium and large farm groups where vertical interval of terrace is less than 300 mm. The medium and large group farmers also used power operated thresher, maize sheller and diesel engine.

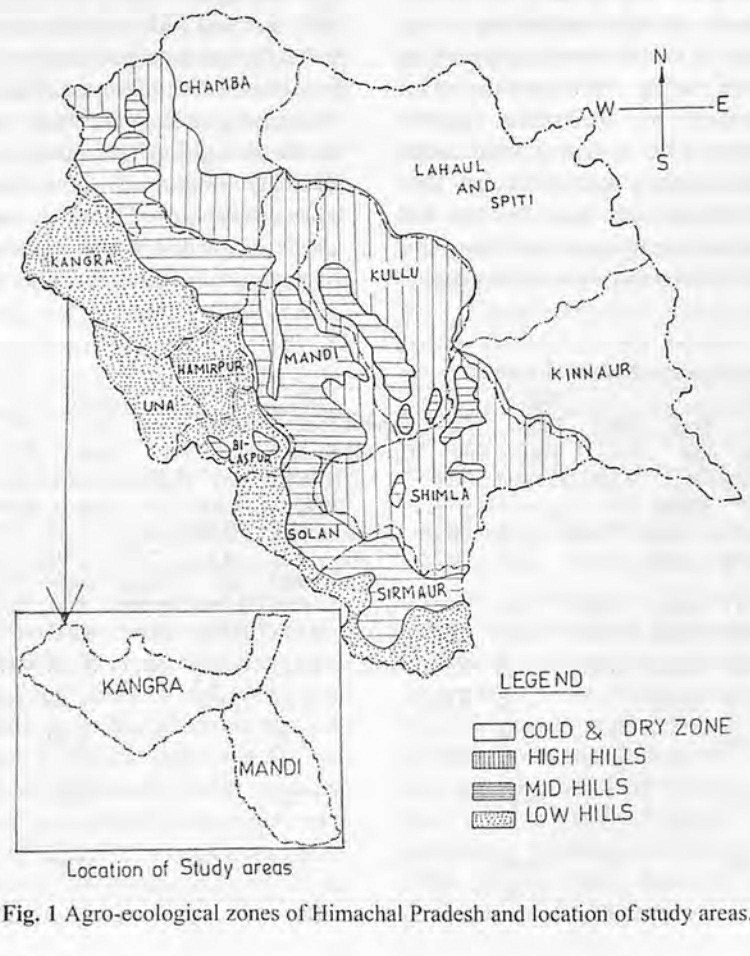

Fig. 1 Agro-ecological zones of Himachal Pradesh and location of study areas.

Hill agriculture system is still human dominated as most of the farming operations are performed traditionally using manual tools and implements like clod breaker, hand tine type weeder, and sickle (**Table 5**). Other operations such as sowing, transplanting, fertilizer/manure application, irrigation, and transportation were performed by human power without much use of tools and implements. The animal power was used more than 80% for ploughing, planking and puddling in both the districts. The power-operated threshers were used in more than 85 % in both study areas. Transportation of farm products was mostly by manual power because of topography and poor network of roads in the farms.

Table 6 shows the average annual uses of power source and matching implements for different operations.

Table 3. Power Source Availability, Different Farm Groups

Farm group	Number of Farmers' surveyed	Power source					
		Animal		Power tiller		Tractor	
		Kangra	Mandi	Kangra	Mandi	Kangra	Mandi
Marginal	39	17 (43.6)	19 (48.7)	-	-	-	-
Small	36	21 (58.3)	20 (55.5)	-	-	1 (4.1)	-
Medium	24	14 (58.3)	15 (62.5)	1 (4.1)	2 (8.3)	2 (8.3)	3 (12.5)
Large	20	14 (70.0)	12 (60.0)	-	-	4 (20.0)	5 (25.0)

Note: Figure in parentheses are percentage of power source.

Table 4. Number of Implements/ Machines Available by Different Farm Groups

Farm group	Number of farmers surveyed	Animal-operated		Tractor/Power-operated					
		Plough	Planker	Cultivator	Disc harrow	Maize sheller	Thresher	Diesel engine	Trailer
Marginal	39	46	41	-	-	-	-	-	-
Small	36	43	40	1	-	-	1	4	1
Medium	24	32	35	2	1	5	4	10	2
Large	20	30	31	7	2	6	12	9	7

Table 5. Percentage Distribution of Use of Farm Tools, Implements and Machines for Various Operations

Farm operations	Manual tools		Animal drawn implements		Power operated machines	
	Kangra	Mandi	Kangra	Mandi	Kangra	Mandi
Land preparation						
-Ploughing	NG	NG	82	74	18	26
-Clod breaking	75	82	25	18	-	-
-Planking	NG	NG	85	80	15	20
-Puddling	NG	NG	94	93	6	7
Sowing*	81	78	18	20	1	2
Transplanting*	34	26	-	-	-	-
Interculture	89	92	11	8	-	-
Plant protection	100	100	-	-	-	-
Fertilizer application	100	100	-	-	-	-
Irrigation	86	90	-	-	14	10
Harvesting	100	100	-	-	-	-
Threshing	8	5	6	7	86	88
Winnowing	100	100	-	-	-	-
Transportation	65	75	12	6	23	19

Note: NG- Negligible, * Labourers are employed without any manual tools.

The average annual uses of animal power were 246 h in Kangra and 237 h in Mandi; of which at owners' farms uses were 66.6 % in Kangra and 60.7% in Mandi, respectively; and for the rest of the time the power was utilized for custom hiring. Farmers with power tillers limited their utilization to ploughing, planking, puddling and threshing. The tractors average annual uses were 682 h and 729 h in Kangra and Mandi of which 23.9% and 24.5% were for land preparation, 15.2% and 13.0% for threshing and 60.2% and 62.4% for transportation, respectively. The tractors' uses were 24.6 % and 25.5% for the owners' farms; 75.4 and 74.5% for custom hiring in Kangra and Mandi, respectively. The maximum use of tractor was for transportation in both districts as small field size restricts the use of tractor in most of the farm operations.

Human power was mostly utilized on hill farms. **Table 7** shows that the men were involved 100 % in ploughing, planking and puddling whereas in other operations their involvement was much less than women's. The women were involved 60-80 % in various operations using mostly low and inefficient traditional tools.

During the study, farmers were asked regarding need for improved farm tools, implements and machines for different farm operations. The responses from various farm groups show that more than 80 % of marginal farmers needed manual and animal drawn implements, whereas small and medium group farms showed keen interest in power tiller with matching implements followed by animal and tractor drawn implements (**Table 8**). However, large farm groups needed mostly tractors with matching implements followed by power tiller and animal drawn equipment. Large farm groups, particularly in low hills, where vertical interval of terraces is less than 300 mm mostly demand tractors.

Steps Suggested for Mechanization

Successful implementation of a mechanization program in rural areas requires effort by policy makers, institutions and extension agents to introduce suitable and efficient technology at farmers' fields. The steps suggested for hill mechanization is based on farmers need and topography of the region:

1. Adequate manual and animal drawn implements should be of designed and developed for meeting the needs of marginal and small farm groups.
2. Appropriate source of farm power should be identified appropriate to the needs of topography and small field sizes. The matching implements should also be developed with identified power source.
3. A system may be developed for enhancing the efficiency and reducing the cost of maintenance of animal power by utilizing it in idle periods.
4. The tools, implements and machines should be light in weight for easy operation in terraces and low cost so that farmers are able to adopt them without any financial burden.
5. State governments should encourage the extension agencies for demonstration of the latest technology at farmers' fields.

Table 6. Average Annual Use of Power Source and Matching Implements for Various Operations, Hours

Power source	Use at own farm		Custom hiring		Total	
	Kangra	Mandi	Kangra	Mandi	Kangra	Mandi
Animal power						
Ploughing	72	79	44	48	116	127
Planking	14	15	8	10	22	25
Puddling	40	31	22	25	62	56
Sowing	12	11	-	10	12	21
Interculture	11	8	-	-	11	8
Threshing	5	-	-	-	5	-
Transportation	10	-	8	-	18	-
Total	164	144	82	93	246	237
Power Tiller						
Ploughing	89	92	45	36	134	128
Planking	23	24	10	10	33	34
Puddling	42	35	14	15	56	50
Sowing	12	15	8	7	20	22
Interculture	-	-	-	-	-	-
Threshing	36	45	35	32	71	77
Transportation	5	10	-	12	5	22
Total	207	221	112	112	319	333
Tractor						
Ploughing	42	48	86	92	128	140
Planking	12	14	23	25	35	39
Puddling	-	-	-	-	-	-
Sowing	4	-	-	-	4	-
Interculture	-	-	-	-	-	-
Threshing	26	31	78	64	104	95
Transportation	84	93	327	362	411	455
Total	168	186	514	543	682	729

Table 7. Percentage of Gender Participation in Various Farm Operation

Farm operation	Men		Women	
	Kangra	Mandi	Kangra	Mandi
Ploughing	100	100	-	-
Clod breaking	24	32	76	68
Planking	100	100	-	-
Puddling	100	100	-	-
Mannuring	42	48	58	52
Sowing	26	31	74	69
Transplanting	33	35	67	65
Interculture	21	18	79	82
Plant protection	73	78	27	22
Harvesting	36	32	64	68
Threshing	48	55	52	45
Transportation	32	36	68	64

Table 8. Farm Tools, Implements and Machinery Required by Farmers of Different Farm Groups

Type of tools, implements and power source	Response of various farm groups, %			
	Marginal	Small	Medium	Large
Manual drawn improved Seed drill, weeder, sickle, maize sheller	55.3	12.9	8.6	5.2
Animal drawn improved plough, clod breaker, seed drill, bar harrow, potato planter, digger	26.2	31.4	28.3	9.7
Light-weight power tiller with matching implements	12.8	20.8	6.5	-
Power tiller with matching implements	5.7	30.6	34.2	28.6
Tractor with matching implements	-	4.3	22.4	56.5

6. Farm equipment should be available on custom hiring in villages through government agencies/ private entrepreneurs.
7. State governments should promote small-scale industries to develop tools and implements to ensure availability.
8. State/central government should start to separate the **Agricultural Mechanization Centre for Hills (AMCH)** on the basis of need.

Conclusions

Although the present status of farm mechanization in the hills of Himachal Pradesh is very low, there is a great scope for its development. About 80 % of the cultivated area falls under low and mid hills, which has potential to grow various crops using mechanical power technologies like tractors and power tillers with suitable matching implements. Improved animal drawn implements are also the need of farmers, particularly, the marginal and small farm ones. In a nutshell, mechanization as a positive measure for improving the economy condition should be taken as a policy by the government. Thus, there is a need to formulate policies, strategies and programs in relation to total demand of farm power in agriculture based on timeliness, cropping intensity and increase in production goals in the rainfed areas of the hills.

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It includes the data about Farm Machinery Statistic of JAPAN

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Tel:+81-(0)3-3291-5718, Fax:+81-(0)3-3291-5717
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The Present State of Farm Machinery Industry

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Outlook of Agriculture

Trend of Agriculture

In 1999 agricultural total products was ¥5,125 billion, accounting for 1.1% of GNP. The imports agricultural products decreased to $40.4 billion in 1996, $37.0 billion in 1997, $34.0 billion in 1998. But it increased to $37.0 billion in 1999-2000.

The agricultural products exports are $1.5-1.6 billion in late years, except $2.3 billion in 1999. In Japan, depends on imports in supply of feed cereals, soybean, wheat and so on. Self-sufficiency rate of food is 40% by calorie base in 2000, cereals 28%, almost the same as preceding year.

Population mainly engaged in farming has been decreasing yet, 2.9 million in 2000,4.5% of total working population. Farm house has decreased 3,120,000 farm houses, in 2000. Among them, commercial household was 75%. Arable land was 4,830,000 ha in 2000. Arable land per one farm family was only about 1.5ha.

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 consumer's need, and to realize safe and environmentally kind agriculture.

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. In 2000 Japanese government enacted guidelines for dietary patterns to improve national dietary, the Food Recycle Law to decrease food waste, the revised Japanese Agricultural Standards (JAS) Law to improve food safety. BSE incident in 2001 directed the government to take necessary measures to assure food security.

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 2001, working hours on 10a paddy field reduced to 34.0 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 a new type 21'st century program for emergency development of agricultural machines has started to develop 31 types machine. 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

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

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer & 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	2,318	1,869	1,921	1,022	1,203	1,121
2000	1,048	2,028	1,433	1,269	583	1,042	861

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

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
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
2000	169,996	72,554	55,386	163,904	52,540	10,648	40,888	33,483
2001	145,557	85,933	47,285	156,598	44,845	8,019	35,685	29,782

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

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 commercial farm household of Feb.1,2000 : riding tractor reached 2,028,000 units ; walking tractor 1,048,000; rice transplanter 1,433,000; head feed combine 1,042,000 (**Table 1**).

Shipments of major farm machinery in the domestic market in 2001 are as follows : riding tractor reached 86,000 units (under 20PS were 19,000; 20-30PS 29,000; 30-50PS 11,000; over 50PS 6,300); walking tractor 146,000; rice transplanter 47,000; combine 36,000 (standard types were 1,495); grain dryer 30,000; huller 23,000. The shipment of safety cabins and safety frames attached to tractors rose sharply to 66,000 units (**Table 2**).

Recently more and more used farm machines are distributed. The rate 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

Amount of Japanese agricultural machines production in 2001 was 483.9 billion yen. Recently amount was 500 billion yen, but in 2001 it have been below this figure. Almost Japanese farmers suspecting Japanese agriculture are elderly people. Their retirement from agriculture has begun. This situation maybe decrease agricultural machines production.

Japanese agriculture has been dividing to two directions. One is professional large scale farmers and the other is hobby small farmers. We can find this tendency in machine sales. Large and small machines shipment are not bad. But middle size machines are not good.

There is clear tendency that small farmers seeking cheap machines. Many makers made cheap type machines already. What do farmers who cannot maintain their farmland because of ageing? They consign their farmland to other farmers. As a result , farmland are concentrating. Large farmers will get bigger and bigger. Agricultural machines makers will response to this situation.

Takayama city in Gifu prefecture is a major place of spinach. Harvesting spinach is hard work. Other almost working of spinach production were mechanized. Only rest working is harvesting. Many spinach farmers have been waiting a spinach harvester.

In 2002, local maker developed spinach harvesters. Spinach harvesters will expand in Takayama. Mechanization of vegetable production has progressed certainly. And development of agricultural machines must have a environment oriented policy.

Trend of Farm Machinery Production

Farm machinery production in 2001 amounted to ¥483.9 billion (11.8% decrease over the preceding year).

Production of the major farm machinery is as follows : Riding tractor 135,353 units, 17.2% down as compared with the preceding year. Seeing by h.p., those under 20PS amounted to 50,847 units, 20-30PS 41,110 units, over 30PS 43,396 units. Production felldown in every class as compared with the preceding year.

The production of walking tractor amounted to 191,941 units, a decrease of 15.8% as compared with the preceding year. 125,591 units for under 5PS, 66,350 units for over 5PS.

The production of combine, which is next to the riding tractor was 36,158 units (a decrease of 12.1%). 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 50,918 units (a decrease of 3.5%), binder (walking type harvesting machine for rice and wheat, barley etc.) 8,172 units (a decrease of 27.6%), thresher 4,421 units (a decrease of 20.9%), grain dryer 33,699 units (a decrease of 12.4%), huller 35,969 units (a decrease of 5.8%), bush cleaner 963,965 units (a decrease of 4.7%), power pest-controller 216,247 units (a decrease of 14.0%) 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 ¥1,265.9 billion (**Table 4**).

According to the governmental survey by Ministry of Agriculture, Forestry, the total sales of farm machinery by Agricultural Coopera-

Table 3. Yearly Production of Farm Machinery

Unit: Number, Million Yen

Year	Farm machinery total		Riding type tractor		Walking type tractor		Rice transplanter		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
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	—	548,473	163,536	228,174	243,995	32,228	56,784	47,795	162,527	7,763	82,832	3,607	6,000	9,896
2001	—	483,856	135,353	190,616	191,941	25,726	50,918	45,068	139,360	6,036	70,422	2,679	6,465	9,854
(2002)	—	245,645	73,809	106,055	91,192	11,321	24,553	24,273					2,901	4,437

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
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	11,291	3,207	1,011,889	23,132	5,586	2,154	41,137	109,469	38,183	14,589	38,476	32,413	33,741	2,175
2001	8,172	2,336	963,965	12,237	4,421	1,624	36,158	99,278	35,969	14,377	33,699	28,512	36,427	6,972
(2002)			569,066				16,238	47,670	15,567	5,351	19,319	14,909	9,648	1,794

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 2002 are Jan. ~ June.

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 (2000 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
1996	2,331	374,334	279,070	415,691
1998	1,840	274,510	200,124	313,107
1999	1,620	274,361	197,069	309,739
2000	1,424	266,454	188,492	301,219

Source: "Statistics on Agricultural Cooperatives—2000 business year" by the Ministry of Agr., Forestry & Fisheries.

tive Association reached ¥301.2 billion in 2000 (¥309.7 billion in 1999) (**Table 5**). Merge Agricultural Cooperative was about 1400. Amount of dealing machines per Cooperatives increase to about ¥210 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 2001 the export of farm machinery amounted to ¥126.2 billion, a decrease of 9.3% as compared with the preceding year. The ratio of exports to the total production amounts to ¥483.9 billion ended 26.1%.

Seeing by the destination, ¥74.2 billion for North America (a decrease of 6.8%), ¥19.0 billion for Asia (a decrease of 4.9%), ¥24.4 billion for Europe (a decrease of 18.0%). For North America, ¥70.3 billion was for U.S.A. , tractor 63,500 units, ¥59.7 billion, which was a major part. Tractors for Asia is about 18,500 units, but maker's shipment is only 1,000 units, others may be secondhand (**Table 6**).

As for the types of farm machinery, tractor was chiefly exported; 108,336 units were exported in 2000 (the total production was 135,358 units). It amounted to ¥79.0 billion. Seeing by horse power, those under 30PS amounted to 75,239 units, those from 30 to 50PS 26,072 units, those over 50PS 7,025 units.

Major farm machinery, next to tractor, is bush cleaner. The total exports were 857,290 units, ¥18.8 billion. The exports of other farm machinery are as follows; walking tractor 51,512 units; power sprayer 33,519 units; lawn mower 51,418 units; mower 35,767 units; chain saw

Table 6. Export of Farm Equipment 2001

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		
1999		149,066		
2000		139,049		
2001		126,173	100.0	U.S.A., France, Korea
Power tiller	51,512	2,850	2.2	France, U.S.A., Spain
Wheel tractor	108,336	78,994	62.6	U.S.A
Seeder, Planter	1,941	1,813	1.4	Korea, Taiwan
Power sprayer	33,519	1,055	0.8	Korea, U.S.A, Taiwan
Duster	6,962	169	0.1	Korea
Lawn mower	51,418	3,768	3.0	France
Brush cutter	857,290	18,824	14.9	U.S.A, France
Mower	35,767	851	0.6	U.S.A., Korea
Combine	1,052	3,407	2.7	Taiwan, Korea, China, Peru
Chain saw	149,344	3,145	2.5	U.S.A., Italy, France
Others	—	11,297	9.2	

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

Table 7. Import of Farm Equipment 2001

Unit: CIF million yen

Year	Unit	Value	Ratio	Major 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		
2000		25,825		
2001		32,603	100.0	U.K., Germany, China
Wheel tractor	3,005	11,565	35.5	U.K., Italy, Germany
Pest control machine	3,558,739	1,866	5.7	China
Lawn mower	56,108	1,976	6.1	U.S.A., Sweden, Germany
Mower	11,979	1,708	5.2	France, Netherlands
Hay making machine	1,094	565	1.7	Germany, France
Bayler	719	1,314	4.0	U.S.A., Germany, France
Combine	167	1,356	4.2	Belgium, Germany
Chain saw	38,714	940	2.9	Germany, Sweden, U.S.A.
Others	—	11,313	34.7	

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

149,344 unit, etc.

Import

In 2001 the imports of farm machinery amounted to ¥32.6 billion, which means an increase of 26.2% over the preceding year.

Followings are the major imported farm machinery: tractor 3,005 units (those more than 70PS were 2,322 units of all the tractor); chain saw 38,714 units, lawn mower 56,108 units, mower 11,979 units, fertilizer distributor 1,942 units. Tractors 1,099 units were imported from U.K., 769 from Italy, 441 from Germany and 432 from France (**Table 7**).

Trend of Research and Experiment

The surroundings of Japanese agriculture are very hard, because of increased imported agricultural products, 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 agricultural mechanization was revised. In 1993 "Urgent Development Program" started for the objective of developing machines critically needed by some farmers, but with low market demand. As a result, new machine like vegetables grafting machine came to market. And from 1998, "A 21st century type Urgent Development Program" including high ability machine to protect environment, to help mechanize working in mountain areas.

In 2001, in the field of farm machinery of public research institutes, there were movement as follows;

Improvement of device spraying precisely with information of fertilization by field mesh. And making of prototype machine which can change fertilizer quantity by soil map. And assessment of rice plant machines which run straight without a operator.

A trial production of automatic measure machine detecting injurious insects. A progress of spot spry machines in orchards and controlling vehicle in slope orchards. A development of small combine for small paddy field in mountain area. A test for a combine with a device making production map. A development of sorting machine for head vegetables. A development of electric system of supplying safety information of agricultural working. ■■

The Ibaraki University at a Glance

by
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Introduction

Ibaraki University was established in 1949 as an enforcement of the 1949 School Education Law. By integrating prewar institutions: Mito High School (Mito Koto-Gakko); Ibaraki Normal School (Ibaraki Shihan-Gakko); Ibaraki Juvenile Normal School (Ibaraki Seinen Shihan-Gakko); and Taga Technical Specialists' College (Taga Kogyo Senmon-Gakko). The integration also instigated the College of Arts and Sciences, College of Education, and the College of Engineering. The conglomeration expanded and grew over the years as the University now consists of five colleges: humanities, education, science, engineering and agriculture.

This papers zeros in on the College of Agriculture which is located in Inashiki-gun, which is called the "Ami Campus". The campus is 60 km north of Tokyo, 10 km from the Tsukuba Science City and 10 km also from the Tokyo International Airport at Narita. The College of Agriculture consists of three departments: Biological Production Science, Bioresource Science and Regional and Environmental Science. The latter was restructured from the former Agricultural Engineering and Agricultural Economics departments which currently have five laboratories in which 10 faculty staff and one technical staff are closely related to the discipline of agricultural engineering. The masteral and doctoral programs of the University are reviewed briefly later.

The Agricultural Production Systems Engineering Laboratory

Prior to the expansion of the University, there was only one laboratory that covers the subject agricultural machinery. Later, this laboratory was reorganized into the Laboratory of Agricultural Production Systems Engineering. Two university professors, Dr. Shoji Moriizumi and the writer are currently in charge of this laboratory. Another professor, Dr. Masakazu Komatsuzaki runs the University Experimental Farm in collaboration with the Laboratory of Agricultural Production Systems Engineering.

The major research subjects in the laboratory are as follows.

- Ergonomic study on the process of mastering tractor operation;
- Study on index for labor stress in agricultural operation;
- Study on energy balance of plant growth;
- Development of plant production system using the mirror duct;
- Environmental control based on plant growth temperature;
- Study on farm reseeding system in sustainable upland farming; and
- Utilization of pyroligneous acid in low chemistry chemical agriculture

Currently enrolled in the Univer-

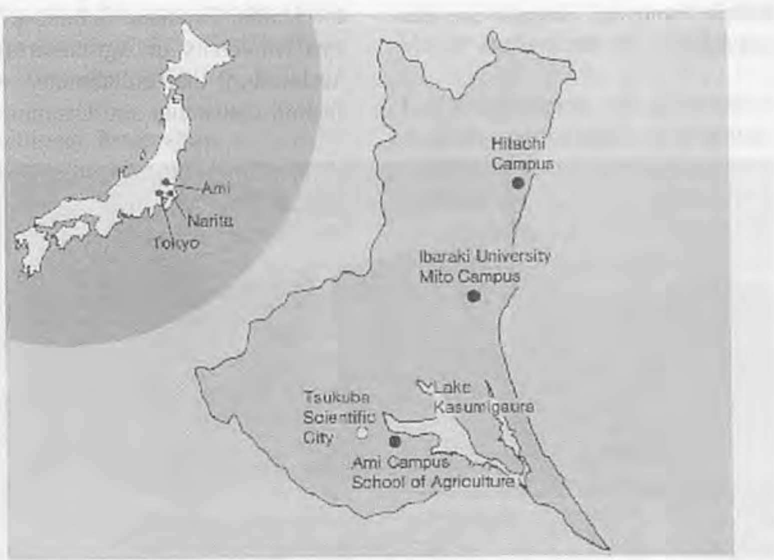

Fig. 1 Geographical location of Ibaraki University.

Fig. 2 View of the main building of the College of Agriculture.

sity's graduate program are two Ph.D. students each from Indonesia and China, and six Japanese students in masteral program. At the undergraduate program, there are currently three senior students and five junior students.

The major facilities are two experimental laboratories for indoor experiments, and a workshop where we can fabricate, assemble and fix experimental equipment, and a plant production room equipped with a mirror duct. A laboratory seminar for all students is held once a week during which current research topics of interest are discussed.

The Graduate Study for Foreign Students

Foreign students are accepted at the Graduate School either as special or regular students in a non-degree program wherein students are expected to focus their study on a specific subject matter area. The program typically lasts for one year. On the other hand, the degree program refers to masteral and doctoral degrees. The former is generally a two-year study program. Students completing their Master's degree can enroll in the Ph.D. program of the United Graduate School at Tokyo University of Agriculture and Technology that collaborates with Ibaraki University and Utsunomiya University. Foreign students are expected to be sufficiently proficient in the Japanese language to attend classes and perform laboratory work since the medium of instruction is Japanese.

Applicants for the special and regular student category must have a Bachelor's degree from an accredited university, and this degree must follow an educational period of 16 years or more.

Applicants to Special Student Course are required to take Level 1 of the Japanese Language Proficiency Test held in early December in Japan. It is possible to take this test in one's native country. The information is available at Japanese embassies or overseas consulates. ■■

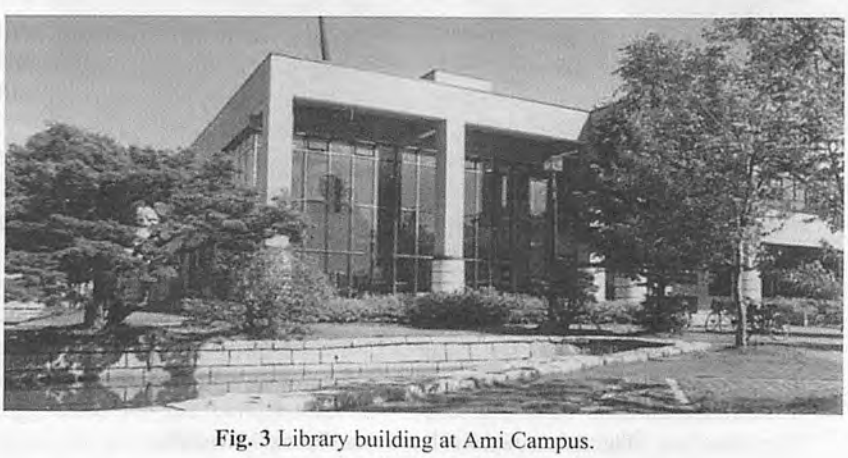

Fig. 3 Library building at Ami Campus.

Activities at the Hokkaido Agricultural Machinery Association

by
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Agriculture in Hokkaido at a Glance

Hokkaido is the northernmost island of Japan and its key industry is agriculture. The land utilized for agriculture in Hokkaido is estimated at 1,199,000 ha which is 24.0% of the country's total farm land. Farm households numbered 69,841 in 2001 and the average cultivated area per farm is 17.2 ha. The area is some ten times larger than farms in other prefectures. The average farm size of cultivated area in Tokachi (center of Hokkaido) is over 30.8 ha that compares favorably the average farm size in Europe.

The total area of paddy fields is 239,100 ha, which is about 8.8% of the national total, upland field is 417,200 ha (34.2% of the national total), and grassland is 539.100 ha (81.9% of the national total). It is recognized that Hokkaido is the typical area of upland and dairy farms.

The number of tractors in Hokkaido is 142,404 and the average number of tractors of a farm is 2.4 units. The average operating area for a tractor is 8.9 ha.

The Hokkaido Agricultural Machinery Association

The Hokkaido Agricultural Machinery Association (HAMA) was organized from the former Agricultural Machinery Industry in Hokkaido in order to better contribute to the sound growth of agriculture in the region. The regular members of HAMA are agricultural machinery industries whose main offices and factories are located in Hokkaido and 36 corporations as shown in the table below. Thirty additional supporting members consist of the agricultural machinery industries with main offices outside of Hokkaido and the branch offices in Hokkaido as well as agricultural machinery trading corporations with offices also in Hokkaido.

Finances and Management

The financial resources of HAMA are membership fees, activating subsidies and contributions. HAMA is administered by a president, two vice presidents, a managing director, an executive director, twelve members of board directors and three auditors. The current President is Mr. Isao Nishitani who is the president of the Star Agricultural Machinery Mfg. Co., Ltd.

Machinery Production

The value of shipment of agricultural machineries sold in Hokkaido in 2001 was estimated at ¥53,012 million yen which includes ¥19,098 million yen for farm tractors and ¥33,914 million yen for farm implements. For another viewpoint, the value of shipment sold in Hokkaido may be divided into ¥15,461 million yen for those manufactured in Hokkaido, ¥21,429 (implement: ¥13,145) million yen for those manufactured in other prefectures and ¥16,122 (implement: ¥5,306) million yen for imported machinery.

Farm Products

The value of agricultural products of the regular members, including overseas export and those sold outside of Hokkaido was ¥19,674 million yen in 2001 and is estimated at ¥19,994 million yen in 2002. The rate of annual increase of farm products is 2.0%. The shipment of machineries for fertilizers, planters, cultivators and crop management was the largest at 26.2% of the total followed by the shipment of crop harvesting implements for upland farming and forage harvesting machinery, 21.7% and 17.5%, respectively. About 70.2% of the annual total production was sold in Hokkaido and the balance was shipped to outside of Hokkaido.

Major Activities of HAMA

1. Dissemination of information about agricultural mechanization and advice.
2. Research and investigation on agricultural mechanization and publishing books, pamphlets and brochures.
3. Testing and inspection of agricultural machineries.
4. Research and promotion in the use and development of agricultural machineries.
5. Undertaking symposia, demonstrations and visit to successful farms.
6. Extending cooperation with government and public officials on

HAMA Regular Members

No.	Name	Main Products	Tel. No.	Fax. No.
1	STAR FARM MACHI. MFG. CO., LTD.	DAIRY & PADDY FARM IMPLE.	0123-26-1121	0123-26-2098
2	TAKAKITA CO., LTD. HOKKAIDO BRANCH	FERTILIZER, DAIRY FARM IMPLE.	011-781-1111	011-788-8178
3	TSUCHIYA MFG. CO., LTD.	DAIRY EQUIP.	011-781-5883	011-783-7107
4	HOKKAIDO KIORITZ ECHO CO., LTD.	SPRAYING IMPLE.	011-891-2249	011-892-6722
5	HOKKAIDO HONDA CO., LTD.	BEAN CUTTER, BUSH CUTTER	011-895-6627	011-895-7021
6	HOKKAI SPRING MFG. CO., LTD.	SPRING FOR FARM IMPLE.	0134-62-3521	0134-62-6086
7	ISHIKARI ZOHKI CO., LTD.	HARROW, FERTILIZER, SPRINKLER	0126-45-2815	0126-45-3515
8	HONDA FARM MACHI. MFG. CO., LTD.	HARROW, HANDLING EQUIP.	0126-45-2211	0126-45-2212
9	HOKKAIDO NIPULO CO., LTD.	ROTARY TILLER, POTATO DIGGER	01238-3-2352	01238-3-2501
10	CIRCLE TEKKO CO., LTD.	BEET TRANSPLANTER	0125-22-4351	0125-24-7126
11	MIYOSHI FARM MACHI. CO., LTD.	BEEN THRESHER	0166-48-8678	0166-47-1208
12	WATANABE AGRI. MACHI. CO, LTD.	BUCKET ELEVATOR, THRESHER	0166-48-2121	0166-48-2100
13	SUGANO FARM MACHI. MFG. CO., LTD.	PLOW, SUBSOILER	01167-45-3151	0167-45-5306
14	ATOM AGRI. MACHI. MFG. CO., LTD.	FRONT & REAR LOADER BUCKET	0166-92-3315	0166-92-3410
15	ISHIMURA TEKKO CO.	COMBINATION HARROW, CULTIVATOR	0166-92-2278	0166-92-2278
16	FUJIMI IRON WORK CO., LTD.	STONE PICKER, POTATO DIGGER	0166-92-1135	0166-92-3053
17	NANPU JIDOSYA SERVICE AREA CO., LTD.	CARROT HARVESTER	0167-52-2511	0167-52-2727
18	KUDOU AGRI. MACHI. CO., LTD.	POTATO & BEET HARVESTER	0155-64-4147	0155-64-5021
19	TABATA AGRI. MACHINES MFG. CO.	FERTILIZER. PLANTER	0155-48-2324	0155-48-2080
20	TSUCHIYA DAIRY EQUIP. MFG. CO., LTD.	DAIRY EQUIP.	0155-37-2161	0155-37-2751
21	TOYO AGRI. MACHI. MFG. CO., LTD.	IMPLE. FOR UPLAND FARM	0155-37-3191	0155-37-5399
22	NOBUTA AGRI. MACHI. MFG. CO. LTD.	POTATO DIGGER, WEEDER	0155-64-5411	0155-64-5398
23	TOKACHI AGRI. MACHI. MFG. CO., LTD.	POTATO PLANTER	0155-62-2421	0155-62-5650
24	FUKUZAWA TRACTOR CO., LTD.	YAM TRANSPLANTER	0155-62-2897	0155-62-3254
25	ROLL CREATE CO., LTD.	WRAPPING MACHINE	0155-62-5676	0155-62-5603
26	HOKKAI AGRI. MACHI. MFG. CO., LTD.	SEEDER, FERTILIZER	0155-62-5051	0155-62-5052
27	YOSHIDA TEKKO CO.	HAY FEEDER	01562-2-2004	01562-2-4332
28	SUDO AGRI. MACHI. MFG. CO., LTD	FORAGE BLOWER, HAY ELEVATOR	01562-5-2650	01562-5-2007
29	NICHINOKI SEIKO CO., LTD.	CULTIVATOR, BEET HARVESTER	01562-5-2188	01562-5-2107
30	IDA CO., LTD	STONE PICKER	0157-23-4493	0157-23-4499
31	SHIBUYA TEKKOSHO CO., LTD.	BARN CLEANER	0157-23-6241	0157-25-4699
32	FUKUCHI INDUSTRIAL CO., LTD.	BEET HARVESTER	0157-36-5714	0157-36-7512
33	KUNNEPPU MACHI. INDUSTRY CO. LTD.	ONION HARVESTER	0157-47-2131	0157-47-4330
34	SHINDOTO AGRI. MACHI. CO., LTD.	POTATO HARVESTER	0157-56-2226	0157-56-3663
35	KIYOSATO AGRI. MACHI. MFG. CO., LTD	POTATO BEET HARVESTER	01522-5-2106	01522-5-2108
36	SANEI INDUSTRIAL CO., LTD.	POTATO BEET HARVESTER, TOPPER	01522-3-2173	01522-3-4133

Abbreviations: AGRI.=AGRICULTURAL, MACHI.=MACHINE OR MACHINERY, IMPLE.=IMPLEMENT, EQUIP.=EQUIPMENT

farm machinery matters.

7. Cooperating with concerned organizations.

Other Activities

1. Quarterly publication of journal named "Nogyo-kikai Hokkaido" (Agricultural Machinery in Hokkaido in Japanese). The journal is distributed to all members of HAMA, public offices, research and experiment institutions and various agricultural organizations.
2. Publication of occasional paper named "Gyomu Tsushin" (in Japanese) reporting on useful information and topics about farm mechanization which is distributed to all members by the electric mailing system.
3. Cooperates with the Hokkaido Prefecture Agricultural Experiment Station in inspecting some agricultural machineries mainly used in Hokkaido. HAMA controls the applications for the inspection from members, submits them to the Experiment Station, and publishes and distributes the results of inspections. About 10 machineries are inspected in a year.
4. HAMA may receive financial support for projects of investigation and development of agricultural machinery from the Japanese government and Hokkaido prefecture. HAMA promotes the project in cooperation with research and investigating institutions. Some of the recent projects pertain to introduction of automatic-control for farm implements.
5. HAMA holds and supports "the International Agricultural Machinery Exhibition" every 4 years in Tokachi area, and holds conferences on soil treatment implements named "Tsuchi o kangaeru kai" (in Japanese) every year in Furano area.
6. HAMA sponsors seminars about technology in cooperation with different industries. HAMA sponsors its technical courses several times a year.

International Exchange

Inquiries about agricultural machinery and technical references have been increased from Korea, Taiwan, East Europe and Siberia. The tours to Thailand and Indonesia in 1996, and tour to Italy in 2000 were held and technical exchange and market research were accomplished. In 2001, the technologist exchange program was conducted between Shenyang, Liaoning Province in China and HAMA. Agreement for technical cooperation was discussed. Agricultural machinery used in Hokkaido has been developed with reference to large machineries made in Europe and North America. However, higher technology of agricultural machinery in Hokkaido has been highly evaluated for small-sized farming. ■■

Education and Research Activities of the Niigata University

by

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General Information

At Niigata University, we enjoy a long history, rich in tradition, the old university being established about 130 years ago. The new university was set up in 1949. At present, the University has nine undergraduate faculties and seven graduate schools, including Humanities, Education, Law, Economics, Study of Modern Society and Culture, Science and Technology, Medical and Dental Sciences.

The number of working staff (only full-time employees) is approximately 2,500 strong. Half of our staff are professors and instructors, 20% are administration staff, and another 30% are technical experts such as nurses at the university medical hospital. There are approximately 13,000 students at the two campuses, Ikarashi and Asahimachi. Some 30% are females and 40% are from the Niigata area.

The University is actively working in close cooperation with like institutions overseas and encourages students to participate in international exchange programs. More than 350 international students are currently enrolled at Niigata University, some of whom are on an exchange program. Lying by the Sea of Japan, Niigata's location makes it one of the important centers of international exchange in the North East Asian region.

Faculty and the Graduate School

Faculty of Agriculture

More than 600 undergraduate students are currently enrolled at the faculty of Agriculture consisting of three departments: Agro-biology, Applied Biological Chemistry and Production and Environment Science. The faculty runs a Field Center for Sustainable Agriculture and Forestry.

There are 31 professors, 23 associate professors and 12 assistant professors in the faculty. Students enrolled in the faculty are expected to earn 124 credit units before graduation.

Students who are interested in agricultural mechanization are encouraged to select the Bio-production Information Engineering Course or Regional Agriculture Course.

Master's Degree Program

Graduate education at the University's Master's Degree Program is accomplished by taking part into the educational and research activities in one of the educational/research groups, whose scope is closely related to majors from the special undergraduate education.

The special undergraduate education term, together with the postgraduate term under the Master's Degree Program consists of a six-year term of education. At the same time, continuing education in the latter three-year postgraduate term (Doctoral Degree Program) is envisioned. Thus, a stepwise integrated educational pattern is obtained.

Education and research activities supervised by different educational/research groups are combined to meet the demands of a more comprehensive education course during the last three-year term. On the other hand, students attending a program on re-education on a vocational base are provided with special classes offered at convenient time, such as during noon and/or at evening hours.

Doctoral Degree Program

The Graduate School covers all majors in the field of science and technology, envisioning education of an integrated type, with smooth transition from the Master's Degree Program toward the Doctoral Degree Program. Students can consult with staff members of the Graduate School in order to obtain a continuing five-year term of high-level specialization through postgraduate education and research activity.

Students coming from private enterprises receive highly qualified guidance to continue and further develop their research abilities. Such students are admitted with already specified research theme. At the same time, their full independence is guaranteed since no restrictions on the discipline of research are imposed by Graduate School.

The Research Group of Bio-production Engineering

There are three groups working on bio-production engineering in the faculty as follows: Laboratory for Agricultural Mechanization, Laboratory for Agricultural Systems Engineering and Laboratory for Crop Production Engineering.

Laboratory for Agricultural Mechanization

The development of new agricultural machineries, variable rate application equipment of granular fertilizer applicators, mechanization of kenaf (jute crop) production using the commercially available equipment on the market, and the development of Web site to modernize the rural areas are the main concerns of the Laboratory. The two staff members of the group are Prof. Masato Suzuki, Dr. of Agr. and Assistant Prof. Yutaka Sasaki, Dr. of Agr.

Laboratory for Agricultural Systems Engineering

Post-harvest handling optimization techniques for various agricultural products, control systems of greenhouse environment, application of neural networks for quality evaluation of fruits and decision support systems for crop production are the major fields of study and research in this Laboratory. The staff members of this group are Prof. Kazuhiro Nakano, Dr. of Agr. and Associate Prof. Yoshitaka Motonaga, Dr. of Agr.

Laboratory for Crop Production Engineering

Farm mechanization, cover crop cultivation for weed control, field efficiency and safety engineering in farm work and livestock management in agricultural field represent the basic lines of study and research of this group headed by Prof. Michiaki Ito, Dr. of Agr. and aided by Associate Prof. Hajime Araki, Dr. of Agr.

International Cooperation

International Academic Exchange

The University has on going international exchange programs with 60 foreign universities from 17 countries. Many students and researchers are provided with opportunities to visit foreign universities through these programs.

Foreign Students Population

At Niigata University, currently enrolled are 357 foreign students from 39 countries. 81% of them are from Asia, especially China; 60% are enrolled in the graduate school programs and 40% of them are female students. The University has established an International Student Center to enable foreign students to attend Japanese classes and to assist them on various educational matters, and in their day to day living.

Liaison Relationship and Research

The University currently runs 133 various research undertaking in collaboration with local private corporations, 58 other joint research projects and 75 commissioned research topics. Through these activities, the University is able to establish and promote the concept of small-letter relationship. In addition, the professors are given the opportunities to liaize with corporate bodies and enhance cooperative research activities. Shown below are five visuals depicting some of research activities and a seminar on information processing. ■■

Fig. 1 Seminar on information processing.

Fig. 2 Mechanization of kenaf production. Forage harvester and wagon are utilized in harvesting the kenaf plant.

Fig. 3 Assembling of the new concept on chemical sprayer.

Fig. 4 Water management system for paddy field attached with auto irrigation gate wireless data communication device and solar batteries.

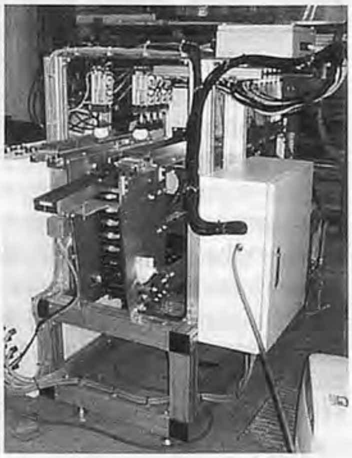

Fig. 5 Development of non-destructive detection system for abnormal eggs using transmittance of some special wavelength.

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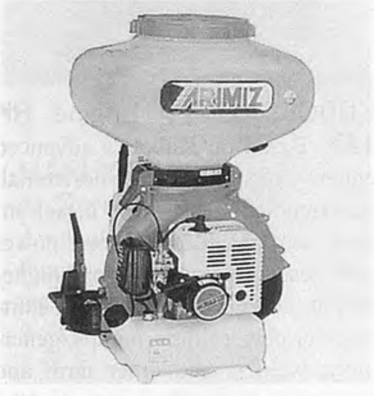
Main Production of Agricultural Machinery Manufactures in Japan

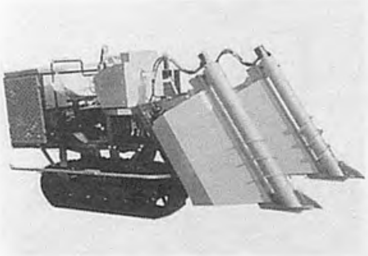
by
Shin-Norinsha Co., Ltd.
7,2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101-0054 Japan

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

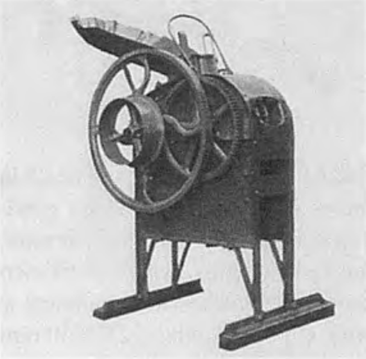
The products are developed and improved for both foreign and domestic markers. For further information please refer to the manufactures contained in the directory.



ARIMITSU Knapsack Power Duster Model SG-7030. Light-weight, compact design, but ensuring to produce bigger air volume due to high performance turbo-fan 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): 360 × 520 × 740mm, weight: 10.5kg, Max. output:3.7ps/7500rpm, Chemical tank capacity:28*l*, 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.



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 TXG23 Tractor. Mounted with powerful and economical 22.5PS water cooled diesel engine. The tractor offers wide range of travelling speeds from approximately 0 km/h to 16 km/h, which offers broad operating application and safe road travelling.

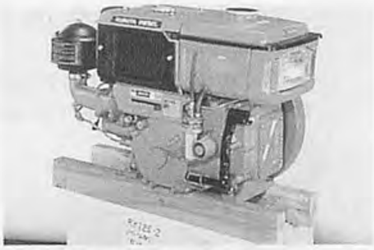
ISEKI SF303 Mower. The 28 hp diesel engine gives you the power you need to deal with all your mowing tasks quickly, while its efficient use of fuel makes it economical as well. Cutting width: 1524/1830 mm, Cutting height: 30-120mm.

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 MX5000 (50HP) 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. This tractor can be operated in dry and paddy field. High performance and great durability!

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.

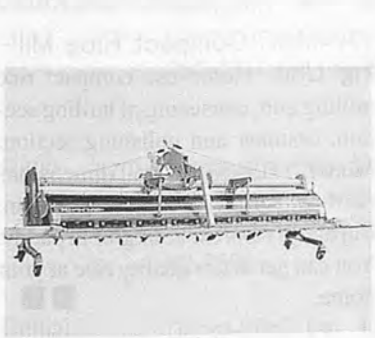


KUBOTA Diesel Engine RK 125. Based on Kubota's advanced engine technology, the horizontal, water-cooled and 4-cycle diesel engine can provide full-bore power with less fuel consumption, higher output, and quick and smooth starting. For power tillers, pumps, generators, welders and other farm and industrial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

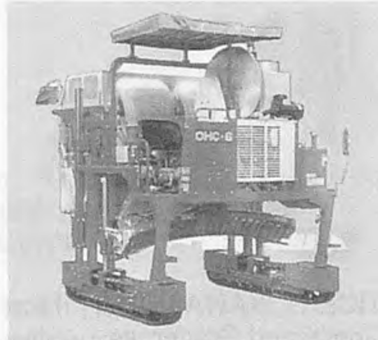
MAMETORA Vegetable Transplanter TP-4. This machine is available in both pot and soil block in seeding transplanting. Application: all vegetable nursery.

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 5.1*l*/mm, max pressure 25 kg/cm^2, Weight: 8.5 kg.



NIPRO Drive Harrow HR-2410B-3S for paddy field. Working width: 244 cm; Required tractor horsepower: 24-40HP.

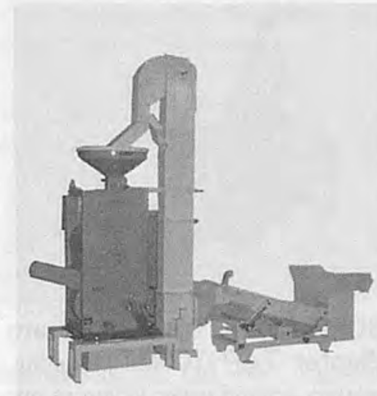


OCHIAI Riding Type Tea Picking Machine OHC-6. Full working width cutter bar. Stepless speed control. Water-cooled Diesel engine 29PS

OREC Cultivator SF40W. Hobby use: Mounted with 2.4 PS(1.8kw).

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: 300*l*. Required tractor horsepower: 20-50PS.

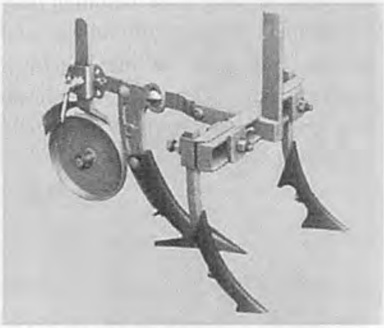


SATAKE Mill Top. Compact Rice Milling Unit including paddy cleaner, Rubber roll husker and friction type rice milling machine. Input capacity: Approx. 650 kg/hr on long grain rice. Required power: 25 PS engine (standard).

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

STAR Mini-Roll Baler MRB 0850. 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 ABLE Potato Planter TAP-100MT. Planting, ridging, ground cover laying in one operation.



SUKIGARA Three-Tine Light Cultivator. Length:51cm, Cultivator width:18 ~ 30cm, Weight:8.5kg .

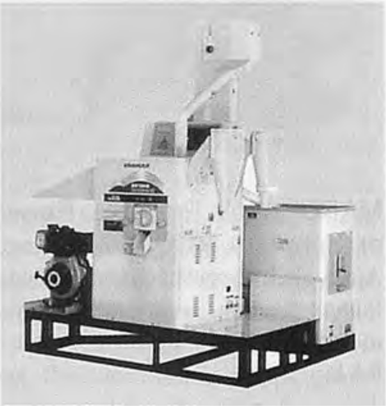
TANAKA 2-Cycle Engine Pure Fire is an environmentally kindly engine that cleared the secondary exhaust fumes control by the U.S. CARB. Both 26cc and 42 types are available. The engine just for the 21st century.

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

UCHIDA Power Tea Picker S-8N & B-3. Handy and simple to opetate. Hair-trimmer type blades protect the tea leaves from damage. You can see the cutting work for transparent case.

YAMAMOTO Rice Whitener Ricepal 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: 21hp, 28hp, 32hp, 37ps, 42hp. Compact, quiet and vibration diesel engines are mounted at the heart of these F-ex series tractors. Engine: vertical, 4-cycle, water-cooled. Transmission: F8 × R8 or F9 × R9. 4-wheel drive.



YANMAR Compact Rice Milling Unit. Home use compact rice milling unit, consisting of hulling section, destoner and polishing section. Model: YHS150. Overall dimensions (L × W × H):1.49 × 1.32 × 1.94m. Capacity: Approx. 150kg/hr in paddy. You can get better quality rice at your home. ■■

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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.

028

Enhancing Pulses Yield through Mechanical Sowing. **Abdul Razzaq,** Senior Subject Matter Specialist (Engg.), Adaptive Research Farm, Sheikhupura, PAKISTAN. **Liaqat Ali,** Assistant Research Officer of the same farm.

The study was conducted to observe the influence of mechanical sowing on mung bean (Vigna radiata); a prospective pulse crop. Manual broadcasting, manual broadcasting plus mechanical ridging and mechanical, straight and cross drilling or mung bean were tested. Drilling was observed to increase mung bean yield significantly over broadcasting and also economically viable. Registering 829.82 kg/ha yield with 26.49 % increase and contributing CBR of 1:27.90, mechanical straight drilling proved to be the best method of sowing to enhance mung bean production.

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Development and Testing of a Hand Weeder. **P. S. Chattopadhyay,** Reader, Dept. of Farm Machinery and Power, Faculty of Agricultural Engineering, BCKV, Mohanpur, 741 252, West Bengal, INDIA. **S. Karmakar,** Lecturer of the same Dept. **Sudipto Biswas**, Ex. B. Tech. Student of the same faculty. **Soumesh Mondal,** Ex. B. Tech. Student of the same faculty.

A hand weeder was developed considering the efficiency, ergonomic feature and cost effectiveness for weeding a number of row crops. It was tested in bare field as well as crop field for its performance evaluation on the basis of field performance. The operational parameters were optimized and again tested in actual field condition with the optimized design. It was found that the optimum shank height and blade angle of the weeder was 13 cm and 20° , respectively. The field efficiency in the bare field was slightly higher than that observed in the crop field and the weeding efficiency was also better. The field capacity, field efficiency and the weeding efficiency of the weeder with optimum settings in the crop field were 0.015 ha./h, 73.33% and 93.16%, respectively.

162

Evaluation and Minimization of Wheat Harvesting: Losses in New Halfa Scheme, Sudan. **Sheikh El Din Abdel Gadir El-Awad,** Associate Professor and Agric. Engineer, New Halfa Research Station, P.O. Box 17, New Halfa, SUDAN.

The study was conducted in 1992/93 and 1993/94 seasons in New Halfa scheme. The objectives were to evaluate the national wheat harvesting losses, effects of the presence of bunds ties in wheat fields on combine harvesting losses and to asses the results of wheat harvesting losses minimization project. The performance of two makes of combine harvesters was evaluated under New Halfa wheat fields conditions. The John Deere combine harvester resulted in lower wheat harvesting losses for the two seasons compared to Claas makes, but the difference was not significant for reasons explained in the text. The technical information that were given to the seasonal combine operators and farmers in 1993/94 season, before and during wheat harvesting operation, were found to be fruitful in reducing wheat-harvesting loss by about 7% compared to 1992/93 season.

The main source of wheat harvesting losses was combine harvester header. Header percent loss increased with delay in harvesting time. The presence of bunds ties in wheat fields increased wheat harvesting losses by 100% compared to the losses in fields with removed bunds ties.

Therefore, it could be recommended that bunds ties in wheat fields should be removed before combine harvesting in order to minimize harvesting losses.

170

Restitution Coefficients of Coated Rice Seeds. **Yang Mingjin**, Lecturer, Engineering Technology College, Southwest Agric. University, Chongqing 400716, CHINA. **Yang Ling**, Lecturer of the same college. **Li Weiqing**, Associate Professor of the same college. **He Peixiang**, Associate Professor of the same college. **Li Qingdong**, Professor of the same college.

Restitution coefficients of coated rice seeds were studied by means of orthogonal method. The tested factors in the study are seed condition (coated or not), moisture content, type of seeds, impacted material, thickness of material and drop height. The major factors and their significant levels affecting the restitution coefficient of coated rice seeds were found through analysis of variance. Testing instrument repeatedly collected data based on kinematical equations, which resulted in high accuracy. ■■

BOOK REVIEW

The Mechanics of Tractor-Implement Performance -Theory and Worked Examples-

(Australia)

by Ross. H. Macmillan

1. Introduction

This book, for engineers and engineering students, is about the functional performance of agricultural tractors - how, and how well, they perform the function for which they are designed - pulling loads. It is not about construction, operation or management but about performance and the factors that determine it. Because it treats the tractor in terms of the fundamentals of the subject, it is not limited to any type or size or make.

This book is written for professional agricultural engineering courses or equivalent subjects for mechanical engineers. It could also form the basis for short courses for practicing engineers. It assumes a 2nd year level of engineering science.

2. Summary

Chapter 1 gives an outline of the subject, a justification for its study and an overview of the main systems in the power train of both the conventional and two wheeled tractor.

The analysis of performance starts in Chapter 2 with the engine performance as a 'given' and extends this, via a simple mechanical analysis, to give the ideal performance of the tractor.

The results of tests that are performed by the testing stations following procedures such as those used by the OECD are presented graphically and explained in Chapter 3. This approach is shown to confirm (within appropriate limits) the analysis presented in Chapter 2.

Chapters 4 and 5 treat both traction theory (Bekker, Reece etc) and empirical analysis (Wismer, Dwyer etc) in terms of the relevant parameters. Both are required for students to understand the subject and to break into the extensive research literature based on these analyses.

Chapter 6 on chassis mechanics covers the fundamentals of the subject appropriate to tractor performance and includes material that has not previously been published in a readily accessible form.

In Chapter 7 all of the factors that determine tractor performance are brought together and their relevance to the selection of a tractor to match an implement and their efficient operation, in terms of performance, are illustrated.

3.Special Features:

The book develops the subject of tractor performance through the common alternative techniques used in engineering analysis:

*ideal (theoretical, simple mechanics),
*experimental (ideal [firm surface], measurement based)
*theoretical (soft surface)
*empirical (soft surface)

This has an incidental didactic purpose that is lost when authors move from one analytical technique to another without any explanation.

The book takes the student / reader through a number of stages from the simple to the more complex, from elementary mechanics of the tractor alone to that for the tractor when attached to an implement.

One of the most significant features of the book is that it treats performance in quantitative terms and illustrates this with many associated graphs. These enable the reader to obtain a picture of the relationships that is not possible in a merely descriptive or numerical presentation.

The tractor on which the book is based was a typical but actual (30+ kW) tractor (now out of production). It is only used to illustrate the principles being explained and thus follows a well accepted engineering approach.

The book is basically analytical but its connection with the 'practical' is through the worked examples and the problems with answers given through the text.

This book is available free of charge on the University of Melbourne.

http://eprints.unimelb.edu.au/archive/00000204/

Total pages -165

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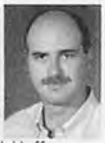
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The Editorial Staff of the AMA requests contributors of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process :

Criteria for Article Selection

Priority in the selection of articles for publication is given to those that -

a. are written in the English language ;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries ;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission ;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams ;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article ;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written on floppy disc.

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a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 offprints of the article and plural writers are given 35 offprints (also sent by surface/sea mail)"
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s) .

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a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy(**A4**).
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features :
   i) brief and appropriate title ;
   ii) the writer(s) name, designation/title, office/organization ; and mailing address ;
   iii) an abstract following ii) above ;
   iv) body proper (text/discussion) ;
   v) conclusion/recommendation ; and a
   vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number.Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included.(e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
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).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
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.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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