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YOSHISUKE KISHIDA

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EDITORIAL

Agriculture in the Doldrums?

Like all other business enterprises, agricultural industries are also affected adversely by stagflation, or, benefit from good times when business is good. This is because agriculture is also linked with the operation of the law of supply and demand, particularly for the input factors of production such as farm machineries and fertilizers. The current world-wide economic recession seems to place agriculture in the doldrums which is felt everywhere, including in the economically advanced countries such as the United States, Japan and in many European countries.

That agriculture and the agricultural machinery business in much of Europe are reeling from the pressure of the EC and the New Round which, in turn, is influenced by the current recession is the impression that I gathered when I attended last November the international meeting of the Club of Bologna in the industrial city and railroad center in northern Italy. The same impression was strengthened further during my visits last March to two famous international agricultural machinery exhibitions in Verona, also in Italy, and the SIMA Show in Paris, France. European farmers, in general, are seemingly reluctant to invest in farm machineries for lack of future outlook. Quite naturally, this air of reluctance trickles down to the farm level where food is produced.

Japan is no exception to these developments or phenomena where the demand for agricultural machineries in 1991 registered a decline. Many attribute this decline to the fact that in the same year, it was estimated that less than 1,500 young men took up agriculture as a career after graduating from agricultural schools and colleges.

Further observations also indicate that elsewhere, not a few young farmers tend to leave the farms where rewards have become less attractive, hence migrate to urban/industrial centers in search of better opportunities. In the process, the aging parents are left behind to tend the farm or also abandon it when age stops them from doing farm chores.

However, these doldrums are nothing permanent as economists are likely to argue. But they do recur at varying periods of time depending on how governments face up to the problems. For us who are committed to the cause of agriculture and agricultural mechanization, we must perceive these doldrums as a challenge instead for all of us to exert greater enthusiasm to promote agricultural mechanization so that together, we can help turn around the trends before they worsen. For if we don't, who will sustain agriculture and the eco-system into the future? Who will help produce food from the land to feed the world's population that increases at the rate of three persons per second? Who will help abet the reduction of farmlands at the rate of one hectare per 14 seconds?

Together, we can help turn around the crisis in agriculture. In a loud voice and in unison, we can and should influence politicians and the governments to put stress and priorities to agricultural projects that sustain food production and farmland conservation so that we and those who shall come after us will not be hungry. Through agricultural mechanization and development of new technology, food production costs could be reduced and profits could be generated for the benefit of everyone.

The AMA renews its pledge to continue to do its share in the promotion of farm mechanization.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April, 1992

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Effect of Disk and Tilt Angle on Field Capacity and Power Requirements of Mounted Plow

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Abstract

A three-disk mounted type disk plow was tested in silty clay loam soil at moisture content 17%. The disk and tilt angle settings used were 42°, 43°, 45° and 16°, 18°, 20°, respectively.

Fuel requirements were increased with the increase in disk angle and tilt angle.

Field capacity was increased with the increase in disk angle and tilt angle.

The field capacity at disk angle setting of 45° and tilt angle of 20° was improved by 57.28% than disk angle setting of 42° and tilt angle 16° and 11.72% more than disk angle setting of 43° and tilt angle 18°.

Farmers are interested to plow more area in less time. It is, therefore, recommended that disk plow at 45° disk angle may be adjusted to obtain maximum performance.

The use of disk plow is also recommended for rocky and problem soils where other tillage implements could not perform the job satisfactorily.

Further studies in different types of soils should be conducted to evaluate the performance.

Introduction

Tillage is the practice of modifying the state of the soil in order to provide conditions favourable to crop growth. The main objectives of tillage are the production of a suitable tilth, the destruction of weeds, the destruction or control of pests and burrying the rubbish and the incorporation of fertilizers into the soil.

The purpose of tillage in agriculture is to alter the physical condition of the soil for optimum plant growth. This change in physical condition has an overriding effect on plant growth since it governs the flow of water and air to roots. However to date, only little is known quantitatively about the mechanisms of tillage, its measure and its efforts on soil properties as related to crop performance.

Plowing the field has been used for centuries for the main agronomic purposes such as: (1) to bury salt accumulations on irrigated land; (2) to bring up clay to mix with surface layers of sand to reduce wind erosion and improve seedbed characteristics; (3) to bury surface gravels on newly reclaimed desert soil; and (4) to dilute and break up layers of relatively impervious clay and hard pans that are reasonably shallow in the soil profile. Nearly all of these plowing experiences have occurred where water is plentiful by irrigation or rainfall. Plowing represents one of the first attempts in a semi-arid environment (Greb 1970).

A research project was designed to study and evaluate the performance of disk plow at variouos settings of disk and tilt angles. The objectives were to study the effect of disk angle and tilt angle on the field capacity and power requirements of disk plow. The performance parameters taken into consideration were speed of operation, depth and width of operation, wheel slip, time lost at corners and adjustments, field capacity, fuel consumption and power requirements. This type of study will provide a guideline to farmers selecting suitable implements.

Experimental Procedures and Methods

To evaluate the performance of a mounted type disk plow, it is absolutely essential to analyse the soil and field conditions.

The Tandojam University Farm was selected to evaluate the performance of disk plow. A rectangular test plot measuring 87.5 m × 42 m was selected for the research work on three disk and tilt angle settings. The parameters studied were tilling speed, tilling depth, tilling width, wheel slip, draft, and fuel requirements and effective field capacity.

All the above performance variables were measured and recorded in accordance with the recommendations of RNAM Test Codes and Procedures for Farm Machinery, Technical Series No. 12 1983, Agricultural Engineer's Year Book 1981-82 and Bukhari et al 1981.

The instruments and machines used in the research work were: Ford-4600 and Fiat-480 tractors, mounted disk plow (3 disks) dynamometer (5 000 lbs), combination square, rafter framing square, measuring tape (50 m), measuring tape (3.5 m), ranging poles, stop watch, soil sampler (core), soil sample containers, meter square frame, half meter scales, white chalk, jerican for diesel, graduated cylinder, electronic balance, oven, camera and tool box.

Machines

A mounted disk plow with three disks manufactured by Massey Ferguson Co. was selected for the field tests. The power source for operating the disk plow was Ford-4600 wheel type tractor with maximum drawbar power of 46 kW. The diameter of plow disks was 530 mm, disk gauge was 5 mm and dish of the disk was 55 mm. The disk and tilt angles used in the study were 42°, 43°, 45° and 16°, 18°, 20°. The experimental field was unplowed since the previous two cropping seasons. The plow is shown in **Fig. 1**.

Fig. 1 Massey Ferguson mounted disk plow.

Fig. 2 Method of obtaining soil sample at different depths.

Fig. 3 Method of obtaining plowing depth.

Fig. 4 Method of obtaining plowing width.

Soil Type and Moisture Content

The soil type available at the Tandojam University Farm was selected for testing the disk plow. The texture of the soil was silty clay loam, pH value 7.8 and total soluble salts (TSS) in percent (ppm) were 0.11. The soil moisture was determined by dry weight basis. The use of core soil sampler is shown in **Fig. 2**.

Working Depth and Width

The working depth was measured with a half-meter scale. The depth was measured from the bottom of the furrow to the surface level of the soil at seven randomly selected places from the test plot. The depth measurement is shown in **Fig. 3**.

The effective working width of the disk plow was determined by using a steel tape measuring the width of fives passes of tilled area and dividing it by 5 to get the average effective working width at five randomly selected places from test plots. The measurement of width is shown in **Fig. 4**.

Fuel Consumption

The fuel tank of the tractor was filled to capacity before testing the

Fig. 5 Method of measuring fuel consumption.

disk plow in the test plot. After plowing the total area of the test plot (87.5 × 14 m), the fuel tank of the tractor was refilled up to the same fuel level with 1 000 millilitre graduated cylinder. The total quantity of diesel fuel needed to refill the tractor fuel tank up to the same mark was recorded. The fuel consumption per hour and per hectare was calculated from the data so obtained. The measurement of fuel consumption is shown in **Fig. 5**.

Field Operational Pattern

The field capacity and field efficiency are influenced by field operational pattern which is closely related to the size and shape of the field, the kind and size of implement. The non-productive time should be eliminated as far as possible with adoption of appropriate field operational pattern. The machine movement pattern used was headland pattern (Hunt 1983) from boundaries and is shown in **Fig. 6**.

Effective Field Capacity

The time lost for every event

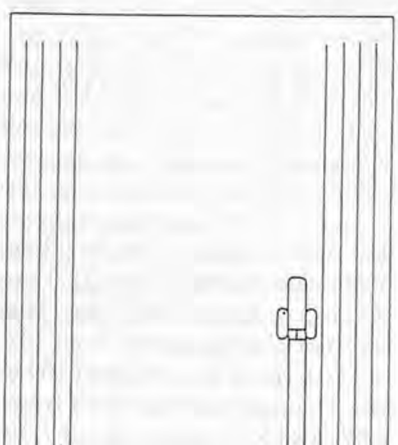

Fig. 6 Headland pattern from boundaries.

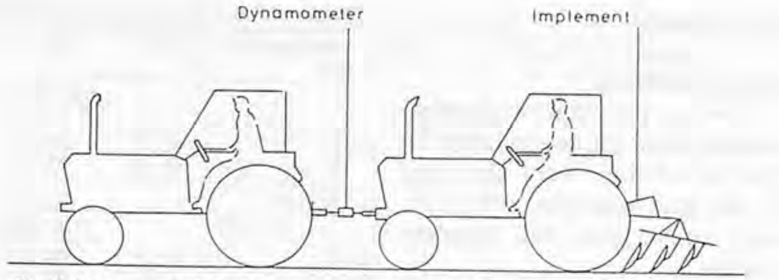

Fig. 7 Measuring of draft for a tractor mounted implement.

such as turning and adjustment was recorded. In calculating the field capacity, the time consumed for real work and that lost should be used. The effective field capacity was calculated by using the formula:

$$C = \frac{A}{T_p + T_t}$$

Where, C = effective field capacity, ha/h., A = area tilled, ha., T_p = productive time, h., T_t = non-productive time, h.

Draft of Disk Plow

A hydraulic type dynamometer was attached to the front of the tractor on which the implement was mounted. Another auxiliary tractor was used to pull the implement-mounted tractor through the dynamometer. The auxiliary tractor pulled the implement mounted tractor with the latter tractor in neutral gear but with the implement in the operating position (Narayanrao and Verma 1982 and RNAM 1983). The draft was recorded for the measured distance of 30 m. On the same field, the implement was lifted out of the ground and the rear tractor was pulled to record the idle draft force. The difference gave the draft of the implement. The measurement of draft is shown in **Fig. 7**.

Measurement of Tilt and Disk Angle

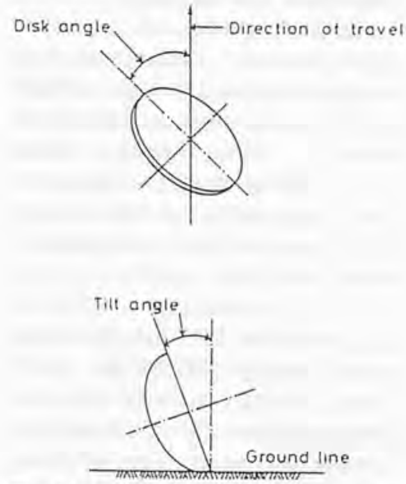

Fig. 8 Identification of disk angle and tilt angle for a disk plow.

The disk angle is the angle in the horizontal plane between the path of the travel and the line passing through the plane of the disk. When the angle is zero the disk will roll along the path of travel. The tilt angle of disk plow is the slant (tilt) backward of the disk from the vertical. The disk and tilt angle is shown in **Fig. 8**.

Results and Discussion

The disk plow performance and operating accuracy differ considerably according to the tilt and disk angle, type of soil, moisture percent, weed infestation and plowing pattern. The measurements and examination of disk plow at three disk and three tilt angle settings were made according to the RNAM Test Code and Procedure for plows for field conditions and machine performance.

Field Conditions

The measurements and observations taken for determining the field conditions were the area of test plot, soil type, pH value, total soluble salts, soil moisture content.

Disk Plow Performance

The observations and measurements made for evaluation of disk plow performance at different disk and tilt angles were the pattern of plowing, tilling speed, tilling width, tilling depth, productive time, non-productive time, travel reduction, draft and fuel requirements and field capacity.

Field conditions — Three disks mounted MF-disk plow was tested during 1987 at the Latif Farm. The land characteristics are given as follows: The field was fallow for two years. The soil type was silty clay loam with pH value 7.8 and total soluble salts (TSS) % (ppm) 0.11, area of block was 16 hectares.

Soil moisture content — The soil samples were taken from 5, 10, 15, 20 and 25 cm depths. The soil moisture varied from 9.60% in the top layer to 21.42% in bottom layer. On the average, the soil moisture content was 16.94%.

Disk plow performance — The experiment conducted to evaluate the field performance of the disk plow at 42°, 43°, 45° disk angles and 16°, 18°, 20° tilt angles. The data was collected to determine the travel reduction, draft requirements, fuel consumption and field capacity of the disk plow.

Travel reduction — The travel reduction of disk plow at different disk and tilt angles is shown in **Table 1**. The travel reduction at disk angle 42° and tilt angle 16° varied from 10.46 to 10.79% or an average of 10.58%.

Table 1 Travel Reduction of Disk Plow at Different Disk and Tilt Angles

Replication	A*	B**	Total travel reduction %	Net travel reduction %
		Disk angle 42°, tilt angle 16°		
1.	42.20	34.90	17.29	10.79
2.	42.35	35.15	17.00	10.50
3.	42.45	33.25	16.96	10.46
Average			17.08	10.58
		Disk angle 43°, tilt angle 18°		
1.	41.45	33.85	18.33	11.83
2.	41.34	33.64	18.63	12.13
3.	41.52	32.85	20.88	14.38
Average			19.28	12.78
		Disk angle 45° tilt angle 20°		
1.	42.30	33.25	21.39	14.89
2.	42.45	33.65	20.73	14.23
3.	42.35	33.83	20.12	13.62
Average			20.75	14.25

A* = Distance travelled with no load, m.
B** = Distance travelled with load, m.

Table 2 Draft and Fuel Requirements of Disk Plow

Replications	Tilling speed m/s	Tilling depth cm	Tilling width cm	Total draft kN	Unit draft N/cm^2	Fuel consumption l/h	Fuel consumption l/ha
			Disk angle 42° tilt angle 16°				
1.	0.87	17.8	109.30	6.57	3.38	—	—
2.	1.00	20.1	110.00	7.85	3.55	—	—
3.	1.03	19.3	111.60	7.34	3.41	—	—
4.	0.90	21.0	109.00	8.00	3.49	4.50	13.06
5.	0.93	19.2	110.80	7.75	3.64	—	—
6.	0.90	18.7	109.50	6.95	3.39	—	—
7.	0.97	18.5	107.00	7.25	3.66	—	—
Average	0.94	19.2	109.60	7.39	3.50	—	—
			Disk angle 43° tilt angle 18°				
1.	0.90	19.0	109.66	9.35	4.49	—	—
2.	0.87	19.5	107.50	8.55	4.08	—	—
3.	0.93	18.0	108.25	9.25	4.75	—	—
4.	0.90	19.5	103.25	7.83	3.89	5.20	16.33
5.	1.03	17.0	103.75	7.44	4.22	—	—
6.	0.97	17.5	106.00	8.76	4.72	—	—
7.	0.87	16.5	110.00	9.45	5.21	—	—
Average	0.92	18.1	106.92	8.66	4.48	—	—
			Disk angle 45°, tilt angle 20°				
1.	0.87	19.5	109.64	9.24	4.32	—	—
2.	0.90	19.0	108.51	8.43	4.08	—	—
3.	0.97	18.5	107.32	8.65	4.36	—	—
4.	0.90	19.5	106.00	7.96	3.85	5.8	14.69
5.	0.90	17.5	110.00	8.35	4.34	—	—
6.	0.93	19.2	107.90	8.76	4.23	—	—
7.	0.90	18.7	108.70	9.12	4.49	—	—
Average	0.91	18.8	108.29	8.64	4.24	—	—

The travel reduction at disk angle 43° and tilt angle 18° varied from 11.83 to 14.38% or an average of 12.78%.

The travel reduction at disk angle 45% and tilt angle 20° ranged from 13.62 to 14.89 or an average, of 14.25%.

Draft requirements — The draft and fuel requirements of the disk plow are shown in **Table 2**. The results indicate that the tilling depth varied from 17.8 to 21.0 cm or an average of 19.2 cm. The width of plowing varied from 107 to 111.6 cm or an average of 109.6 cm. The total draft differed from 6.57 to 8 kN or an average of 7.39 kN. The unit draft varied from 3.38 to 3.66 N/cm^2 or an average of 3.5 N/cm^2.

The draft requirements at disk

angle 43° and tilt angle 18° show that the depth of plowing varied from 16.5 to 19.5 cm or an average of 18.1 cm. The width of plowing deviated from 103.25 to 110 cm or an average of 106.92 cm. The total draft of plowing varied from 7.44 to 9.45 kN or an average of 8.66 kN. The unit draft differed from 3.89 to 5.21 N/cm^2 or an average of 4.48 N/cm^2.

The draft requirements at disk angle 45° and tilt angle 20° show that the depth of plowing varied from 17.5 to 19.5 cm or an average of 18.8 cm. The width of plowing differed from 106 to 110 cm or an average of 108.29 cm. The total draft varied from 7.96 to 9.24 kN and averaged 8.64 kN. The unit draft deviated from 3.85 to 4.49 N/cm^2 or an average of 4.24 N/cm^2.

The fuel consumption of disk plow at disk angle 42° and tilt angle 16° recorded was 4.5 litres per hour and 13.06 litres per hectare; at disk angle 43° and tilt angle 18° the fuel consumed was 5.2 litres per hour and 16.33 litres per hectare; and at disk angle 45° and tilt angle 20° the fuel consumption found was 5.8 litres per hour and 14.69 litres per hectare.

Field capacity — The field capacity of disk plow is given in **Table 3**. At disk angle 42° and tilt angle 16°, the time lost was 0.039 hour (140.4 sec.) for the test plot and the field capacity was 0.206 hectare per hour. The time lost at corners and breaking headland was recorded and deducted from the total time taken for plowing to obtain the productive time. At disk angle 43° and tilt angle 18°, the time lost was 0.045 hour (162 sec) for the test plot and field capacity obtained was 0.29 hectare per hour. At disk angle 45° and tilt angle 20°, the time lost in plowing the test plot was 0.034 hour (122.4 sec) and field capacity obtained was 0.324 ha/hr.

Table 3 Field Capacity of Disk Plow at Different Disk and Tilt Angles

Area tilled (A) ha	Productive time (T_p) h	Non Productive time (T_t) h	Effective field capacity $= C = A/(T_p + T_t)$ ha/h
	Disk angle 42°, tilt angle 16°		
0.1225	0.553	0.039	0.206
	Disk angle 43°, tilt angle 18°		
0.1225	0.377	0.045	0.290
	Disk angle 45°, tilt angle 20°		
0.1225	0.343	0.034	0.324

Conclusions and Recommendations

The conclusions drawn from the present research work on different disk and tilt angle settings of mounted disk plow are:

1. At higher disk angles, the travel reduction increased and at higher tilt angles the travel reduction decreased.
2. As the disk angle was adjusted from 42° to 43°, the total draft and unit draft were slightly increased. However, when the disk angle was shifted from 43° to 45°, the total draft and unit draft were slightly reduced.
3. Fuel requirements were increased with an increase in disk angle and tilt angle.
4. Field capacity was increased with an increase in disk angle and tilt angle.

Farmers are interested to plow more area in less time. It is, therefore, recommended that disk plow at 45° disk angle may be adjusted to obtain maximum performance.

The use of disk plow is also recommended for rocky arèas and problem soils where other tillage implement could not perform the job satisfactorily.

Further studies in different types of soil should be conducted to evaluate the performance of the disk plow.

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Effect of Soil Type and Condition on Field Efficiencies of Tillage Implements

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Abstract

The study was carried out to determine the effect of different soil types and conditions on the field efficiencies of tillage implements. Three common types of soil, viz; clay loam, silt loam and sandy loam in their firm and loose conditions were considered for investigating their effect on the field efficiencies of cultivator, disc harrow, chisel plow and paraplow mounting on MF-375 tractor. It was found that increase in soil texture coarseness increased field efficiencies of cultivator, chisel plow and paraplow in firm soil condition but decreased in its loose form. The field efficiency of disc harrow increased with the increase in soil texture coarseness both in firm and loose conditions. The study further established that loosening enhanced field efficiencies of the tillage implements put to investigation as soil texture coarseness increased but at retarding rate and, consequently, negative values were obtained for chisel plow and paraplow while operating in sandy loam soil.

Introduction

The rate at which a machine can perform its intended function is one of the most important considerations in determining its ability to meet with the timeliness and cost per unit area for the operation. Field efficiency is an index of the actual performance of a machine in a field. It is the ratio of effective field capacity to theoretical field capacity, expressed as percent. Field efficiency depends upon: (a) soil type and its condition, (b) shape, slope and size of field, (c) kind of implements, (e) operating method, (f) tractor power and (g) operator's skill.

In Pakistan, tillage operation consumes the most time of the tractor. The most commonly used implement for tillage is the tine-tiller known as cultivator. Chisel plow and disc harrow are also gaining popularity. Recently, imported paraplow has been introduced which has two side slanting shearing blades with riveted shares at the end. It is deep plowing implement which breaks soil in tension, contrary to chisel plow, without disturbing level and bringing lower layers upward. As the tillage implements are soil engaging tools, the soil type and its condition are the most important factors affecting their field efficiencies.

The study was undertaken to determine the effect of different soil types and their conditions on the field efficiencies of tractor mounted cultivator, disc harrow, chisel plow and paraplow.

Materials and Methods

The study conducted during February and March, 1988 as a programme of Adaptive Research, Sheikhupura. Clay loam silt loam and sandy loam are the main types of soil in Pakistan. The effect of these three types of soil in firm and loose condition on the field efficiencies of cultivator, disc harrow, chisel plow and paraplow was evaluated in the study.

The loamy soil was found unsuitable for running the experiment. After strenuous efforts, private land was found in village Ahdian, district Shekhupura which contained clay loam, silt loam and sandy loam soils, confirmed also in laboratory testing, in three individual plots each of 688 m × 100 m size. All the three soils were in unplowed form, i.e., firm condition and had moisture contents in the range of 10 to 15%. Each plot was divided into 8 sub-plots measuring 86 m × 100 m land. In each plot, 4 sub-plots were reserved for firm soil condition and other four loosened with cultivator used once.

Cultivator, disc harrow, chisel

Table 1 Specification of Implements

Implement	Specification
Cultivator	Local made, 13 tines.
Disc harrow	Imported, NARDI, Offset 16 discs.
Chisel plow	Imported, AGRIC, 3 tines.
Paraplow	Imported, HOWARD, 2 tines.

plow and paraplow of the specifications given in **Table 1** were operated once in sub-plots mounting with tractor, MF-375, 75 H.P. Cultivator, disc harrow and chisel plow were run in unrestrained linkage condition. The depth of paraplow was maintained to 50 cm with the help of gauge wheel.

Actual strokes in operating the implements in each sub-plot were counted. The working width of each implement was obtained dividing the short width of sub-plot by the number of strokes in operation. A length of 50 m was marked in each sub-plot and the time required by implements to cover it was taken from a watch. Ten readings of distance — time were noted for each implement operation in sub-plots. Average travelling speed was computed by dividing distance by time. The theoretical field capacity of each implement was calculated by multiplying working width with average travelling speed.

The total time taken by an implement to cover a sub-plot was noted from a watch. The effective field capacity was derived by dividing the area of each sub-plot, i.e., 8 600 m^2 by the total time taken by an implement while operating in it. The field efficiency of each implement was determined by dividing the effective field capacity by the theoretical field capacity. The change in field efficiencies was computed by subtracting their resultant values, obtained in firm and loose soil conditions, from each other.

Results and Discussion

Table 2 illustrates the field efficiencies of cultivator, disc harrow, chisel plow and paraplow computed from the effective and theoretical field capacities which were derived from the time covering each treatment plot, working width and average travelling speed attained in firm and loose conditions of clay loam, silt loam and sandy loam soils.

Table 2 Field Efficiencies of Implements in Different Soil Types and Conditions

Implement	Soil condition	Working width (m)	Average travelling speed (m/sec.)	Theoretical field capacity (ha/h)	Total time (h)	Effective field capacity (ha/h)	Field efficiency (%)	Change in field efficiency (%)
Clay loam soil								
Cultivator	Firm	2.85	1.42	1.46	0.78	1.10	75	+8
	Loose	2.85	1.58	1.62	0.64	1.34	83	
Disc harrow	Firm	1.55	1.36	0.76	1.59	0.54	71	+4
	Loose	1.55	1.15	0.64	1.79	0.48	75	
Chisel plow	Firm	1.19	1.00	0.43	2.53	0.34	76	+11
	Loose	1.19	1.24	0.53	1.87	0.46	87	
Paraplow	Firm	0.75	1.00	0.27	4.78	0.18	68	+8
	Loose	0.75	1.20	0.32	3.58	0.24	76	
Silt loam soil								
Cultivator	Firm	2.85	1.46	1.50	0.75	1.15	77	+5
	Loose	2.85	1.53	1.57	0.67	1.29	82	
Disc harrow	Firm	1.55	1.10	0.61	1.95	0.44	73	+3
	Loose	1.55	1.15	0.64	1.76	0.49	76	
Chisel plow	Firm	1.19	1.10	0.47	2.32	0.37	79	+7
	Loose	1.19	1.30	0.56	1.79	0.48	86	
Paraplow	Firm	0.75	1.10	0.30	4.10	0.21	70	+4
	Loose	0.75	1.15	0.31	3.74	0.23	74	
Sandy loam soil								
Cultivator	Firm	2.85	1.60	1.64	0.66	1.30	80	+1
	Loose	2.85	1.54	1.58	0.69	1.25	81	
Disc harrow	Firm	1.55	1.46	0.81	1.41	0.61	75	+2
	Loose	1.55	1.35	0.75	1.48	0.58	77	
Chisel plow	Firm	1.19	1.20	0.51	2.10	0.41	80	−5
	Loose	1.19	0.95	0.41	2.77	0.31	75	
Paraplow	Firm	0.75	1.15	0.31	3.91	0.22	71	−4
	Loose	0.75	0.90	0.24	5.37	0.16	67	

Cultivator

In clay loam soil, the cultivator gave field efficiencies of 75% and 83% in firm and loose soil conditions, respectively. The field efficiency of the cultivator increased by 8% in loose clay loam soil over its firm condition. While operating in silt loam soil, the cultivator registered field efficiency of 77% in firm condition and 82% in loose condition. An increase of 5% in field efficiency of the cultivator in loose silt loam soil over its firm condition was observed. The field efficiency of the cultivator to the level of 80% and 81% was obtained in firm and loose sandy loam soils, respectively. The increase of only 1% in field efficiency of cultivator in loose sandy soil over its firm form was obtained.

Disc Harrow

The operation of disc harrow in firm and loose clay loam soil recorded 71% and 75% field efficiency, respectively. An increase of 4% in field efficiency of the disc harrow in loose clay loam soil over its firm condition was obtained. In silt loam soil, the disc harrow gave a field efficiency of 73% in firm condition and 76% in loose condition with an increase of 3%. The field efficiency of the disc harrow was 75% in firm sandy loam soil and 77% in loose form with an increase of 2% over the former condition.

Chisel Plow

The use of chisel plow in firm clay loam soil showed field efficiency of 76% and in loose condition of 87% with an increase of 11%. In firm silt loam soil, the field efficiency of chisel plow was 79% and in loose condition was

85% with an increase of 7%. While running the chisel plow in firm sandy loam, field efficiencies of 80% and in loose condition of 75% were observed. Loosening of firm sandy loam soil decreased the field efficiency of chisel plow by 5%.

Paraplow

In firm clay loam soil, 68% field efficiency was obtained for the paraplow. The loosening of clay loam soil recorded 76% field efficiency with an increase of 8%. The field efficiency of paraplow was 70% in firm silt loam soil and 74% in loose condition with an increase of 4%. The paraplow in firm sandy loam soil registered 71% field efficiency. However, in loose sandy loam soil, the field efficiency was only 67% with a decrease of 4%.

Conclusions

1. The field efficiency of the cultivator increased as the texture of soil becomes coarser under firm condition. However, in loose soil condition, the increase in texture coarseness decreased the field efficiency.
2. With an increase in texture coarseness, the field efficiency of disc harrow increased in firm soil as well as in loose soil condition.
3. For the chisel plow, the increase in texture coarseness increased field efficiency in firm soil condition but decreased in loose form.
4. The field efficiency of the paraplow also increased with an increase in soil texture coarseness under firm condition but not under loose condition.
5. Loosening the soil enhanced the field efficiency of the cultivator, disc harrow, chisel plow and paraplow but at a decreasing rate as the soil texture became coarse. As a result, the effect of soil loosening on field efficiencies of chisel plow and paraplow became negative in sandy loam soil. ■■

Development of a Basin Lister as an Attachment to Power Tiller

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Abstract

For conserving rain water in dryland a single row basin lister as an attachment to power tiller was developed. The unit is a rear-mounted ridge type plow activated by a cam arrangement. It forms basins (discontinuous furrows) in dry lands during summer ploughing at regular intervals which conserves the soil moisture for the utilization of crop at its critical stages. The performance of the unit in conserving the soil moisture at different depths and its influence in increasing the crop yield was studied in comparison with the other moisture conservation methods.

Introduction

Dry farming as it is presently understood is the profitable production of useful crops, without irrigation on lands which receive annual rainfall of 20 inches or less. The potential of the dry farming lands can be increased in the near future by adopting a suitable package of practices aimed at optimizing utilization of available moisture potential through improved soil and water management. Yields are not always proportional to the amount of precipitation. Generally, yield levels are determined by the amount of precipitation above the basic minimum required to enable the crops to achieve maturity. It is, therefore, important in dryland farming to have even a relatively small amount of water stored in soils prior to sowing of crops. Listing is the process of formation of alternate furrows and ridges on the land to conserve soil and moisture. As such there is no power tiller drawn implement available for use in dry farming. Hence, a basin lister as an attachment to power tiller has been developed for use of power tillers in dry farming.

Basin Listing

Listing or ridging are terms that are used to describe the formation of alternate furrows and ridges on the land. When small dams are created at intervals in the furrow it is known as basin listing. The creation of a multitude of small basins in the cultivated field is an effective way of retaining moisture in areas of low rainfall. The simplest way to create these basins is to set the land up in ridges and furrows and to build a small dam wall at intervals in the furrow with the help of a lister. The listers operated by a cam are periodically lifted while working where furrows are not formed and this results in the formation of dammed furrows. This complete cultivation technique aids in the control of soil erosion, soil moisture and promotes high crop yields. It has great merit in low and erratic rainfall regions.

Method and Materials

The principle of operation of the equipment is that the basin listing is done by lifting the ridger through a cam and follower arrangement. The cam is mounted to the wheel axis and oscillates the 'U' shaped follower frame hinged at the front of the power tiller chasis on both sides. The ridger tyne is pivotted near the hitch pin of the power tiller and provided with a slider in the transverse direction. The cylindrical slider accomodates itself inside the corresponding slot on each side of the follower frame. When the follower is lifted, the ridger tyne is also lifted along with it allowing the slider to move longitudinally in the slot. For uniform penetration, a dead weight box is also attached to the cam follower frame. As the plain rim wheel cuts the edges of the basins, a spiked wheel with castor action is provided with support arms from the power tiller handle. It ensures uniform basin formation by controlling the depth of operation and also removes the drudgery of the operator. The unit is rear mounted and fitted to the hitch bracket assembly of the power tiller. It weighs 51 kg and additional dead weights are added for perfect balancing. The draft requirement is 75 kg which is within drawbar capacity of the power tiller. The wheel slip is negligible. The basin lister unit with the power tiller is shown in **Figs. 1** to **3**.

Specifications

The basin lister was evaluated for its performance on moisture storage in dryland for cotton - black gram cropping pattern. The field trials were laid out as per split plot design with the following four treatments and three replications:

a) Power tiller operated basin lister:
   Forming basins of 120 cm length, 30 cm width and 15 cm depth with 45 cm distance in between basins.
b) Broad beds and furrows:
   Forming 120 cm width bed with 30 cm wide channels on both the sides.
c) Compartmental bunding:
   Dividing the field into compartments of size 400 × 300 cm by forming bunds.
d) Conventional method:
   Sowing behind the plough and covering it.

The soil moisture was measured at 15, 30 and 45 cm depths in all the trial plot at regular intervals for the entire crop period. The rainfall during the crop growth was recorded. The yield obtained from each treatment of the trial field was measured and recorded.

Overall length, width and height
: 200 × 55 × 100 cm
Weight of the unit
: 51 kg
Number of listers
: One
Lister width
: 37 cm
Lister depth
: 33 cm
Spacing between basins
: 45 cm
Ground wheel diameter

Fig. 1 Basin lister.

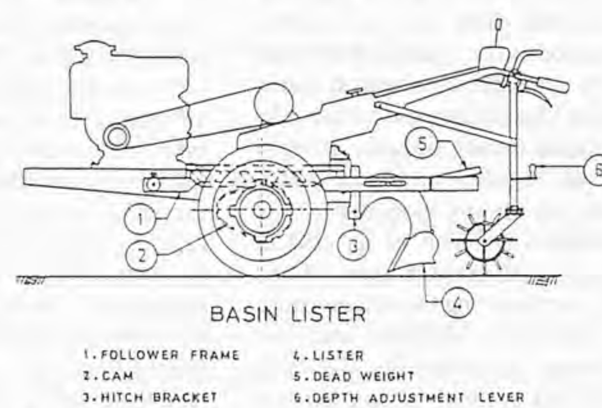

Fig. 2 Basin lister.

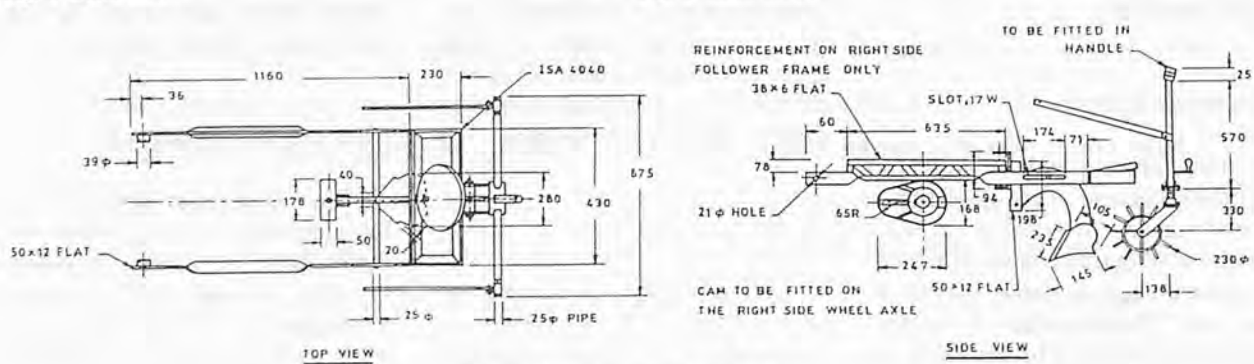

Fig. 3 Extended view of basin lister.

: 58 cm
Cam shape
: Radial
Type of follower
: Flat
Drive for cam
: Power tiller wheel axis
Basin size (L × B × H)
: 120 × 30 × 15 cm
Power
: 8-10 hp power tiller

Results and Discussion

The soil moisture status in different soil moisture conservation methods for different stages of the crop growth is presented in **Figs. 4** to **11**. The yield of the main crop and inter-crop obtained from the trial plots is represented in **Fig. 12**. Comparing **Figs. 4** and **5** it can be observed that the soil moisture conserved at 15 cm depth is increased from 25% to 35% in the basin lister treatment whereas the moisture availability is almost similar in the other systems except in the conventional method where the increase is by 4% (28 to 32%). Hence, it can be said that the higher moisture is conserved in the shallow depth of soil in the basin lister treatment during the pre-sowing and crop establishment. The soil moisture status at different depths is almost similar in all the treatments during the hoeing and weeding and flower initiation stages of the crop as seen in **Figs. 6** and **7**.

During the square formation stage of the crop the soil moisture available is greater in the basin lister treatment in spite of lesser rainfall received and the moisture observed for the crop growth as seen in **Fig. 8**. The soil moisture status is similar in the basin lister treatment for all the three depths of soil during the boll formation stage of the crop as presented in **Fig. 9**. From **Figs. 10** and **11**, it can be stated that the soil moisture conserved is more and the soil moisture depletion pattern is also uniform in the basin lister treatment inspite of the lesser rainfall received during the maturity stages of the crop. It is also observed that the moisture conserved in the basin lister treated field prior to the maturity stages of the crop has been utilized by the crop for its maturity and further growth.

From **Fig. 12** it can be observed that the basin lister treatment yields more when compared to other moisture conservation methods. The average increase in yield of the main crop and inter-crop is 105 kg/ha and 40 kg/ha, respectively, when compared to the conventional method. Since

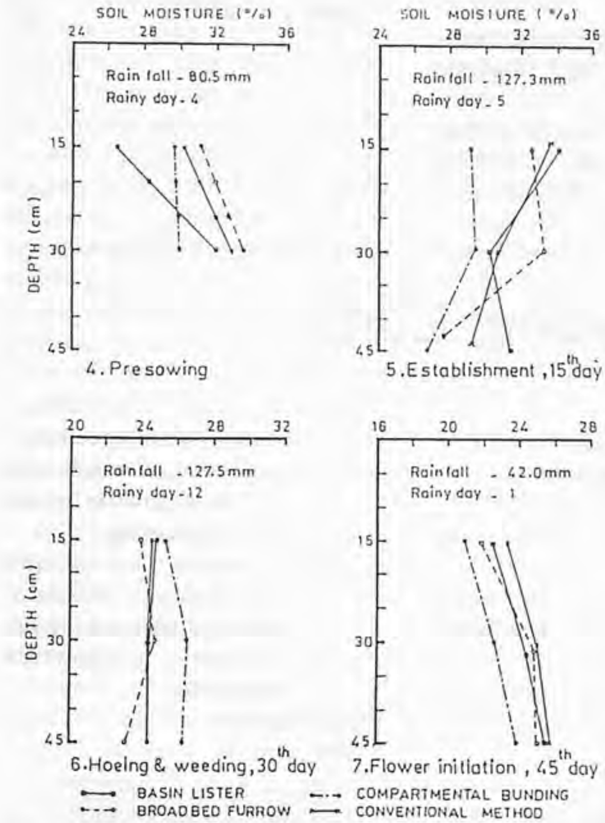

Fig. 4-7 Soil moisture status in different moisture conservation methods.

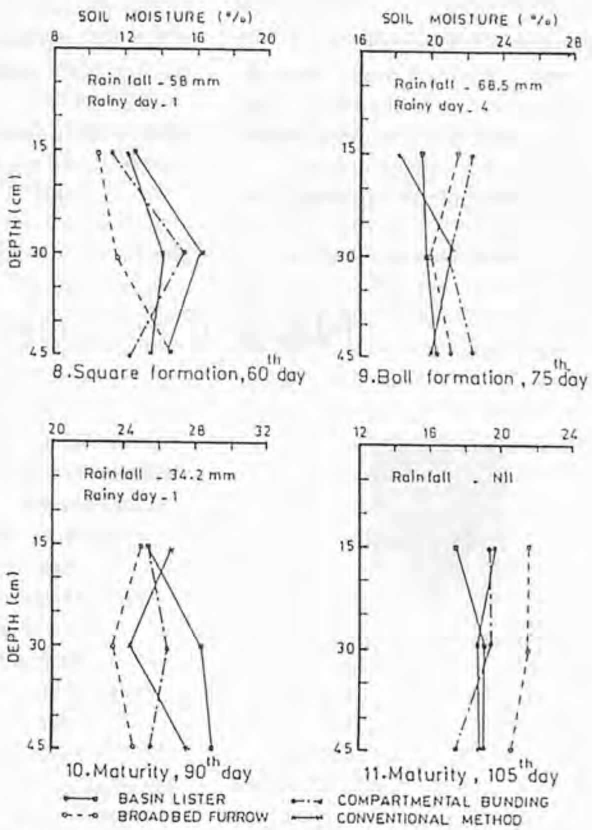

Fig. 8-11 Soil moisture status in different moisture conservation methods.

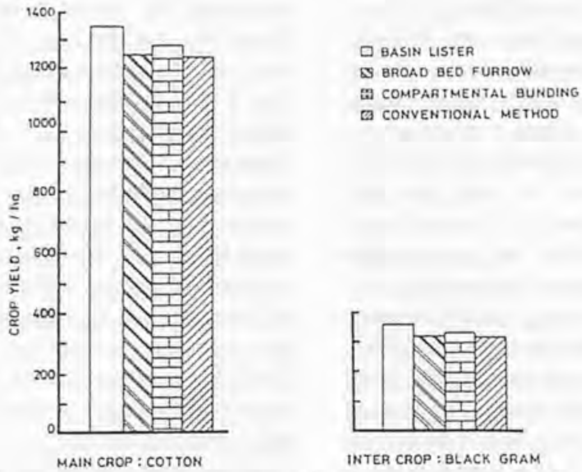

Fig. 12 Yield of crops under different moisture conservation methods.

the other farming operations carried out in all the treatments are similar, the increased yield of crop in the basin lister treatment can only be attributed to the increased soil moisture conserved and stored for utilization by the crop during the critical stages.

Cost-benefit Analysis

Increased yield of main crop obtained from basin lister treatment over conventional system: 105 kg/ha (mean value)

Increased yield of intercrop obtained from basin lister treatment over conventional method: 31 kg/ha

Additional cost benefit obtained from basin lister farming (Rs. 7.5/kg of kapas and Rs. 5/kg of black gram): (105 × 7.5) + (31 × 5) = 802.50 + 155.00 = Rs. 957.50

Cost of operation of basin farming with power tiller (Rs/ha): 339.35

Net benefit derived due to the basin lister treatment: = 957.50 − 339.00 = Rs. 618.50/ha

Conclusion

The basins formed prior to the sowing of crop in rainfed farming at regular intervals conserve adequate soil for the utilization of crop at its critical stages. Significant increase in yield is observed in cotton and black gram under rainfed conditions. An amount of Rs 620/ha is realized as net benefit by way of increased yield due to power tiller basin listing in dry farming.

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New Co-operating Editor

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Design Aspects and Performance of an Axial-flow Vegetable Seed Extracting Machine


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Introduction

Vegetables are an important part of the human diet, rich in vitamins, protein, minerals, carbohydrates and roughage. The area planted to vegetable crops in India is estimated to be about 4 million ha with a production of about 44 million tons. Still the per capita vegetable consumption of 120 g is less than half of the national norm of 280 g. One of the major causes of low vegetable production is the shortage of good quality seeds. Lack of improved methods and mechanical devices for seed extraction of vegetable crops are among the main limitations in the production of quality seed.

Present practices — Seed extraction from ripe fruits of vegetables, viz., tomato (*Lycopersicon esculentum*), brinjal (*Solanum melongena*), chilli (*Capsicum annuum*), watermelon (*Citrullus vulgaris*), squashmelon (*Citrullus vulgaris* var. *fistulosus*), cucumber (*Cucumis Sativus*), longmelon (*Cucumis melo* var. *Utilissimus*) etc. is currently carried out mostly manually. Manual techniques include crushing of the fruits with packer, trampling under feet, squeezing with hands and splitting with hand tools followed by scooping the seed with hand. Manual seed extraction is unhygenic, tedious and highly time- and labour-consuming. It often leads to physical injuries to the hands and feet of the workers. For chillies, wet and dry seed extraction is fairly cumbersome and painful due to the pungency emmitted by the fruits during manual crushing. Hand scooping of the seeds from the cut fruits of cucumber, watermelon, squashmelon, longmelon and brinjal is also injurious to the fingers. Non-availability of trained and experienced labour for manual seed extraction is another serious constraint. Besides, manual seed extraction practices are also slow and expose the seeds to adverse weather that results in seed loss and deterioration of seed quality. Hence a machine for extracting seeds from the freshly harvested vegetable fruits assumes critical significance for the development and growth of a viable vegetable seed production programme.

Review of Literature

Nicholos (1971) reported the development of a mechanical seed extracting machine for extraction of tomato, brinjal, watermelon and chilli seeds. The machine had the drawback of being complex in design and costly. Singh (1984) developed a technique for separating the tomato seeds from pulp after crushing the fruits manually. Kalra et al (1983) developed a manually operated tomato seed extractor which comprised a rotary cylinder with corrugations and a helix fixed on its surface, a stationary expanded metal concave, a feed hopper and a holding frame. Reed (1984) developed a pressurised water spray system which eliminated fermentation for cleaning and separating the muskmelon seeds.

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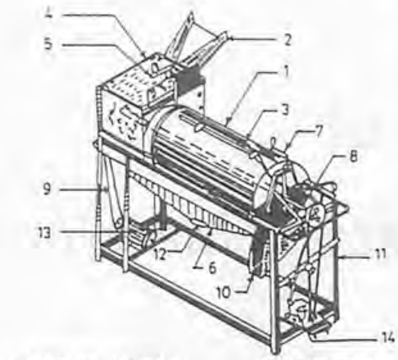

1. Crushing chamber
2. Feeding trough (Chute)
3. Water spraying pipes
4. Primary cutting unit cover
5. Feed regulator
6. Seed collecting chamber
7. Pulp size regulator
8. Rotor shaft
9. Driving belt
10. Pulp outlet
11. Frame
12. Seed outlet
13. Electric motor
14. Water pump

Fig. 1 Isometric view of axial-flow vegetable seed extracting machine.

Table 1 Specifications of Axial-flow Vegetable Seed Extraction Machine

Item	Dimension
Overall length (mm)	1 950
Overall width (mm)	950
Overall height (mm)	1 400
Length of rotor (mm)	1 745
Diameter of rotor (mm)	325
Number of crushing blades	12
Number of rakes	12
Spacing between blades (mm)	68
Tip to tip diameter of conveying rakes (mm)	300
Width of concave (mm)	360
Length of concave (mm)	900
Concave opening sizes (mm)	5, 10 and 13
Radius of curvature of concave (mm)	330
Length of primary cuttting chamber (mm)	340
Width of primary cutting chamber (mm)	320
Depth of primary cutting chamber (mm)	418
Length of crushing chamber (mm)	880
Diameter of water sprinkling pipes (mm)	25
Diameter of sprinkling pipe holes (mm)	3
Power of electric motor (kW)	2
Total weight of the machine (kg): i) With motor	195
ii) Without motor	164

Materials and Methods

Design considerations — The following design aspects were considered in the development of a vegetable seed extracting machine:

i) Suitability for wet seed extraction.
ii) Axial-flow of the material inside the machine.
iii) Power requirement below 2 kW.
iv) Suitability for extracting seeds of different vegetables.
v) Size reduction of large fruits.
vi) Provision for feed regulation to suit different vegetables.
vii) Provision for pulp regulation.
viii) Outlets for seed and pulp ejection.
ix) Provision for easy replacement of concave screen for different types of vegetables.
x) Provision of efficient water sprinkling.
xi) Simple construction.

Construction features — The axial-flow vegetable seed extracting machine comprises a frame, a cylindrical casing, a feeding chute, a primary cutting chamber, a crushing-cum-separation chamber, axially-mounted cutting knives and rakes, water sprinkling system, regulating gates and seed and pulp outlets. A schematic view of the machine showing different components is given in **Fig. 1**. Specification of the machine are given in **Table 1**.

Frame — The frame is made of mild steel angle iron sections. It has rectangular shape. It is well braced to provide rigidity to mount and support other members of the machine.

Feeding chute — A trapezoidal-shaped sheet metal feed trough is bolted to the primary chamber. It is inclined at an angle of 20°C with the horizontal to ensure easy feeding of vegetable fruits into the primary cutting chamber. A hinged plate is provided to allow entry of fruits into the cutting chamber and check the backward throw of fruits.

Primary cutting chamber — The primary cutting chamber is made of M.S. sheet. It has openings at front end and on the side. It has five stationary blades to act as counter teeth. Its top is covered with a movable lid.

Rotor shaft — Blades for primary cutting, sweeping and fine crushing together with the rakes are mounted on the rotor shaft supported on ball bearings at each end **(Fig. 2)**. The cutting blades are of varying lengths and arranged in two rows, move in between two stationary counter blades or teeth in the cutting chamber. The blades are bolted to the radial arms made of M.S. channel section. The blades are arranged in four rows on the rotor shaft.

Rakes are fitted to the rotor shaft in such a way that each rake is bolted to two adjacent sleeves. The angle of inclination of rakes is adjustable. The crushing blades and conveying rakes are spirally mounted on the rotor shaft **(Fig. 3)**.

The sweeping and crushing blades together with the rakes rotate inside a cylindrical casing. On the lower side is provided a stationary concave screen. The cruching blades cut and crush the fruits into small pieces and detach the seeds while the rakes move the

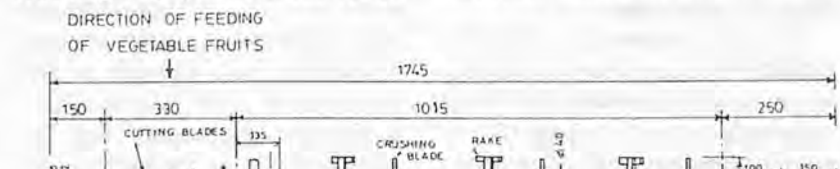

Fig. 2 Mounting arrangement for blades and rakes on rotor shaft.

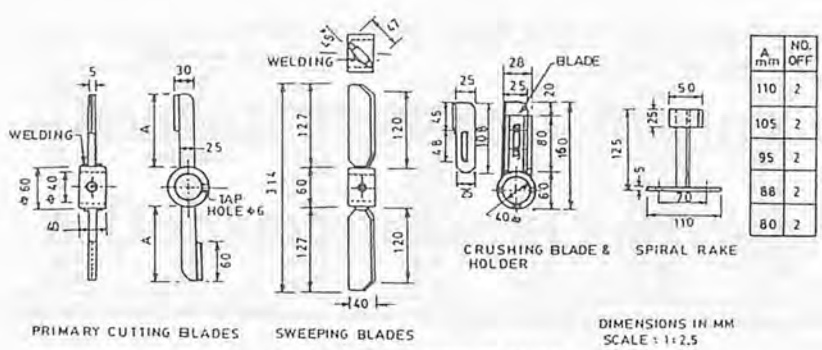

Fig. 3 Different types of blades.

pulp axially along with shaft to eject it out through the pulp disposal outlet.

Feed adjusting gate — The feed adjusting gate is a M.S. plate of semi-circular shape which can be moved vertically up and down with the help of a hand-actuated screw.

Crushing and collection chamber — This chamber is made up of two parts, namely; a stationary concave on the bottom and a casing on the top which can be easily opened. The casing is made of a sheet metal. It has sloping sides and a seed outlet at the lowest point. Seed outlet is made of M.S. pipe.

The upper casing is made of M.S. sheet and is semi-circular in shape. It is hinged to the main frame to facilitate easy opening and closing. Several holes of 3 mm diameter are drilled in a line along the top of the upper casing to match the holes on sprinkling pipe.

Waste outlet — A pulp or waste outlet is provided at the outer end of the crushing chamber. It has a downward slope for easy disposal of the waste material.

Water sprinkling system — The water sprinkling system comprises a centrifugal pump, three sprinkler pipes and connecting rubber hoses **(Fig. 1)**. Two sprinkler pipes of 25 mm diameter and 130 cm length are provided on both sides of the crushing chamber while one pipe of 67 cm length is welded to the upper casing. These are all, in turn, connected to the pump through a hose.

Concave screen — The concave screen is basically a semi-circular sieve with round holes. It is supported on five semi-circular M.S. flats of 175 mm radius of curvature. The concave screen is easily removable and is held in position by the top cover.

Mode of operation — Ripe fruits are fed into the primary chamber and sliced into small pieces by the rotating blades and stationary counter blades. The cut fruits enter the crushing chamber where these are further cut and crushed by the curring and crushing blades. Separation of seeds from the pulp is accomplished by the water sprinkling jets while the pulp is carried axially by the conveying rakes to the waste outlet. The seeds and water escape through the concave openings. An appropriate concave screen is selected to suit different seed sizes. As 5 mm screen is used for tomato, brinjal and chilli, 10 mm for squashmelon, longmelon, cucumber and small seeded watermelon varieties and 13 mm for summer squash and large-seeded varieties of watermelon.

The discharge from the seed outlet is dropped on a stationary screen placed on a water tub. This screen retains the seed while the water is collected in the tub. The seeds are subsequently fed into a conical tub **(Fig. 7)** filled with clean water for washing and cleaning. **Figs.** 4 to 6 show the axial flow vegetable seed extracting machine in action.

The machine is operated by a 2 kW, 1 400 rpm electric motor. It requires three persons for its operation — two for feeding the vegetable fruits and one for removing the seed from screen below the seed outlet.

Method of testing — axial-flow vegetable seed extracting machine was tested on ripe fruits of common Indian vegetables, namely; tomato, brinjal, chilli, summer squash, watermelon, squashmelon and cucumber. The machine was operated at 300 and 400 rpm. Five replications were used for each test. Sample weight

Fig. 4 Vegetable seed extracting machine being used for brinjal seed extraction.

Fig. 5 Vegetable seed extracting machine being used for chillies seed extraction.

Fig. 6 Vegetable seed extracting machine being used for tomato seed extraction.

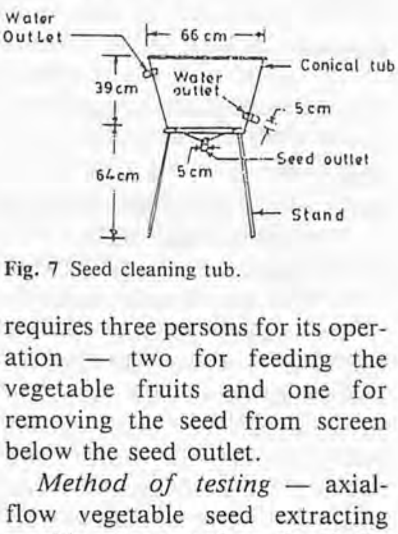

Fig. 7 Seed cleaning tub.

Table 2 Comparative Data of Seed Extraction with Vegetable Seed Extracting Machine and Manual Method

Vegetable	Vegetable seed extraction with machine					Manual seed extraction			
	Feed rate (q/h)	Seed output (kg/man-h)	Seed loss (%)	Seed germination (%)	Cost (Rs/kg)	Seed output (kg/man-h)	Seed germination (%)	Seed loss (%)	Cost (Rs./kg)
Brinjal	5.0	1.83	1.87	84.00	1.87	0.15	83.11	Negligible	16.55
Tomato	19.3	1.26	5.86	76.66	2.72	0.22	73.37	-do-	11.21
Chilli	4.6	3.14	2.72	78.80	1.09	1.65*	73.20	-do-	1.51
Summer squash	3.1	1.56	2.48	74.04	2.20	0.83	69.00	-do-	2.99
Watermelon	7.8	1.20	5.70	86.00	2.86	0.43	84.00	-do-	5.78
Squashmelon	3.3	2.20	28.59**	88.00	1.56	0.95	86.40	-do-	2.63
Cucumber	—	0.47	5.00	84.64	7.26	0.11	79.36	-do-	22.32

* Seed extraction output of dry chillies. ** Percent seed recovery from the pulp outlet. It was not considered as seed loss as the seeds could be recovered during washing with water.

for each test varied between 10 and 100 kg depending upon the availability and size of the vegetable fruits. For a given vegetable, the sample weight for each replication was kept constant.

Vegetable fruits were fed into the machine only once except the chillies, crushed fruits for which were collected from the pulp outlet and refed twice into the machine to ensure complete seed extraction. The separation and cleaning of the seeds was carried out manually by means of a funnel-shaped seed separation and cleaning tub (**Fig. 7**). The clean seeds were dried and weighed to determine the seed loss. The following expression was used to compute the seed loss:

Percent seed loss

$$= \frac{S_2}{(S_1 + S_2)} \times 100$$

where,

S_1 = weight of seeds collected from the seed outlet

S_2 = weight of seeds passing through the pulp outlet

The output capacity of the machine, seed loss, germination count and cost of seed extraction were noted. The cost of the machine, driving motor and labour were accounted for calculating the cost of seed extraction. The performance of the machine was compared with manual seed extraction, for which the sample weight varied from 5 to 25 kg depending upon the fruit size. Tomato fruits were crushed and trampled under the feet and allowed to ferment for 48 h. Brinjal fruits were crushed manually by using a wooden mallet or packer. For cucurbits, the fruits were cut into halves and the seeds together with the flesh were scooped out. The seeds were later separated from the fermented material by decantation. In the case of chillies, the sun-dried material was beaten by a mallet and the seeds separated by winnowing. The seed output capacity loss, germination count and cost of extraction were calculated for manual extraction as well.

Results and Discussion

The performance data of the axial-flow vegetable seed extracting machine on different vegetable fruits is given in **Table 2**. Data on manual seed extraction is also recorded in **Table 2**. Feed rate of vegetable fruits with seed extracting machine varied from 310 to 1 930 kg/h for different vegetables.

The seed extraction rate varied from 0.47 to 3.14 kg/man-hr for different types of vegetable fruits. The seed extraction output was 0.47, 1.20, 1.26, 1.56, 1.83, 2.20 and 3.14 kg/man-hr for cucumber, watermelon, tomato, summer squash, brinjal, squash melon and chillies, respectively. The seed loss for all vegetables except squash melon was below 5.86%. The seed germination was over 79% in all cases except tomato and summer squash. The germination count for mechanically extracted seeds was higher than for the manually extracted seeds. This could be attributed to the fact that immature and unhealthy seeds were discarded during washing of the seeds for the machine extracted seeds. The cost of seed extraction with machine was usually below Rs. 2.86/kg* seed except for cucumber for which it was Rs. 7.26/kg.

The seed extraction output for manual methods varied from 0.11 kg to 1.65 kg/man-hr. Seed germination varied between 69 and 86.4%. The cost of manual seed extraction varied between Rs. 1.51 and Rs. 22.32 per kg. It is worthwhile to mention that drying of chillies was a major handicap in manual seed extraction. The cost on the labour required for handling and supervision during drying of chilli has not been accounted for in manual seed extraction. Considerable seed loss occurs during drying due to fungi and other microbial activities.

To sum up, it is observed that seed extraction with axial flow seed extraction machine was easier, faster and cheaper as compared to the traditional practice of manual seed extraction. The axial-flow vegetable seed extracting machine was found to be suitable for wet seed extraction of most Indian vegetables. The machine is now being commercially produced by two local manufacturers at Ludhiana, Punjab. Over three dozen units have been sold in the country and two units have been exported to Vietnam.

(Continued on page 28)

*US$1 = Rs. 7.00.

Development and Testing of a Donkey-drawn Cultivator-cum-seeder

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Abstract

There is enormous potential for using the donkey as a draught animal for field operations in the West-African semi-arid tropics where soils are light and sandy. The existing donkey-drawn implements, made of iron, are too expensive. A low-cost cultivator-cum-seeder to be pulled by a donkey was designed, developed, and tested in the Republic of Mali. The cultivator is made of wood and iron. It can be used for inter-row weeding and pre-sowing shallow tillage. It covers about 0.1 ha/h and its performance is comparable to the commercially available cultivator (Hoe Asine). The seeder can be used to sow pearl millet and sorghum in hills about 50 cm apart and in rows spaced up to 90 cm. It covers approximately 0.2 ha/h while sowing in rows spaced 50 cm apart. The actual cost of the cultivator-cum-seeder is approximately 30,000 CFA (US$100).

Acknowledgement: Help received from Dr D. Zerbo, General Manager of Societe Malienne d'Etude et de Construction de Materiel de Agricole (SMECMA), to fabricate the donkey-drawn implements is gratefully acknowledged.

Introduction

Draught animal power can be an appropriate and sustainable technology to intensify agriculture for small farmers in Africa. Draught animals are being actively promoted and there are now 8-10 million working animals in sub-Saharan Africa (Starkey, 1986). The donkey is the most numerous equine in the West African semi-arid tropics and plays an important role in rural life for carting and as a pack transporter. It has enormous potential for use in field operations where soils are light and sandy (Fielding, 1987).

In many parts of the West African semi-arid tropics land is abundant and most farmers still use hand cultivation techniques. The primary obstacles to increasing the cropped area are scarcity of labour and low work rate of manual seeding and weeding operations. Many farmers determine the size of their cropped area by their capacity for weeding (Newman et al, 1980). Animal-drawn implements can perform weeding six to seven times faster than manual weeding. However, adoption of animal-drawn weeders is very low due to infrequent practice of line sowing (Sargent et al, 1981). Animal-drawn seeders could play an important role in adoption of line sowing, but these seeders which cost about $170 each are considered too expensive in most of semi-arid Africa. These facts clearly establish a need for low-cost implements for line-sowing and inter-row weeding.

Sowing in hills is a common method of seeding pearl millet and sorghum in semi-arid West Africa. Attemps were made to develop a low-cost implement for sowing in hills and inter-row cultivation. This paper reports on development of a donkey-drawn cultivator-cum-seeder, tested in Mali during rainy seasons 1987-89.

Materials and Methods

Development of a Donkey-drawn Cultivator

A low-cost cultivator to be pulled by a donkey was designed and fabricated in Mali (**Fig. 1**). It consists of a frame made of a 1-m long wooden plank with two rigid beams. Three duckfoot tines or a blade are attached to the frame with the help of simple clamps designed for the purpose. The clamps can be fixed on the frame at a desired spacing. Two small wheels are also attached to the frame. The position of the duckfoot tines and the wheel can be adjusted with respect to the frame, which helps in controlling depth of cultivation and facilitates transport of the implement. The cultivator can be hitched to a donkey with the existing harness, used on donkey carts. In a preliminary field trial, the cultivator worked well for inter-row weeding on flat land. To reduce the cost, it was modified to work with a single-wheel instead of two without much adverse effects on its stability. The design of the clamps was also modified to help fabrication and adjustment of tines, and the wheel was replaced by one readily available in the market. Three units of the cultivator were fabricated at the workshops of Division de la Machinisme Agricole (DMA) located at Samanko, and Societe Malienne d'Etude et de Construction de Materiel de Agricole, SMECMA (largest manufacturer of farm implements in Mali), located at Bamako. The actual cost of the cultivator was approximately $65.

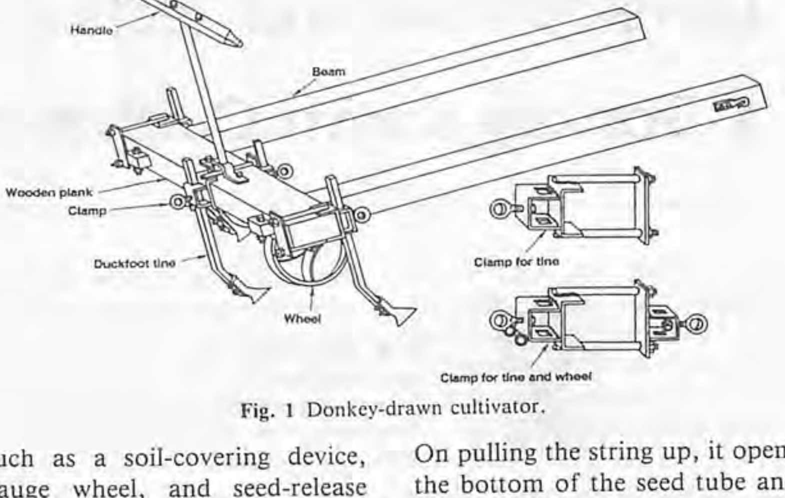

Fig. 1 Donkey-drawn cultivator.

Development of a Donkey-drawn Two-row Hill Seeder

A two-row donkey-drawn seeder for sowing in hills was assembled in Mali. Some of its components, such as furrow openers and seed metering device, were fabricated at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India, whereas other components such as a soil-covering device, gauge wheel, and seed-release mechanism were developed and fabricated at Cinzana in Mali. It consists of a wooden main frame (same as for cultivator), on which an iron wheel (diameter 32 cm), seed-divider bowl, and two hoe-type furrow openers are fitted with clamps. The seed is dropped by hand, which gets divided in two parts at the seed bowl, and passes through plastic tubes to reach the furrow openers where it is held on the seed trap. The operation of the seed release mechanism allows the seeds to fall in a bunch or hill. The seed trap and release mechanism consists of a spring-loaded rectangular sheet-metal piece and a string tied to its one end. It keeps the bottom of the seed tube closed. On pulling the string up, it opens the bottom of the seed tube and allows seeds to fall out. As soon as the string gets released it closes the tube again. Initially, the seed release mechanism was actuated by pulling the string manually but later modifications were made to operate it by a lever attached to the gauge wheel. The seed-release device operates twice for each complete turn of the gauge wheel and drops seeds in pockets about 50 cm apart.

During the preliminary field trials, the operator was not able to drop the seeds properly through the wooden bowl because of lack of practice and it could be a potential impediment for adoption of the seeder. Therefore, the seed-divider wooden bowl was replaced

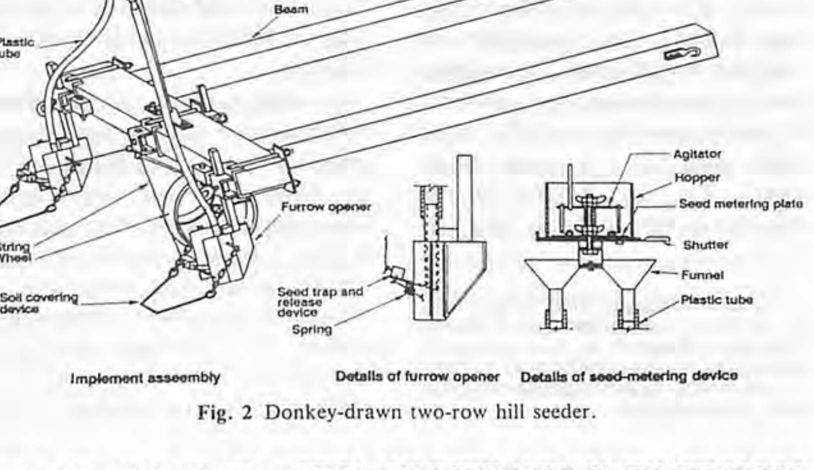

Fig. 2 Donkey-drawn two-row hill seeder.

by a simple seed hopper made of sheet metal with a stationary-opening type, gravity fed, seed-metering device, where the size of the metering hole can be selected by aligning the appropriate hole on the metering plate with the fixed opening at the hopper bottom. The metering hole size, in the range of 2-8 mm, controls the seeding rate, and its selection depends on the seed-size. A shutter is provided at the bottom of the hopper to stop dropping of seeds when desired. An agitator is also provided in the seed box to maintain steady flow of seeds through the metering device. The agitator is manually operated and merely moves the seed back and forth across the selected metering hole. The wheel used in the seeder is similar to the one being used on the cultivator (**Fig. 2**).

Testing

Field tests were conducted at three places (Samanko, Cinzana, and Koporo) having sandy loam, loamy sand, and sandy soils, respectively. The donkey-drawn cultivator was tested at Cinzana for weeding in a pearl-millet crop, sown in rows at a spacing of 75 cm. The cultivator fitted with telescopic beams and a spring type dynamometer was used in another field measuring about 0.5 ha to assess its work rate and draft requirement for shallow tillage (depth 5 cm). A field trial was conducted at Samanko to compare the performance of the donkey-drawn cultivator (**Fig. 3**), with Hoe Asine, a commercially available cultivator made of iron. The trial was conducted in a randomised-block design with three replications. The plots were about 30 m long and 3 m wide and the soil was in friable condition. Both the implements were fitted with 3 duck-foot sweeps, each 15 cm wide, for inter-row weeding in maize crop sown in rows spaced at about 100 cm. The pull force, actual width of cut, depth of cut, distance travelled, and time required were recorded for each implement. The trial was repeated at Cinzana and Koporo also. Testing of the seeder (**Fig. 4**) was done at Cinzana and Koporo only. Spacing between hills of seed, number of seeds per hill, depth of seed placement, and time required to cover a given area were recorded.

Fig. 3 Field testing of the donkey-drawn cultivator.

Fig. 4 Field testing of the donkey-drawn two-row hill-seeder.

Results and Discussion

It was observed that the weeding effciency of the donkey-drawn cultivator was about 80% of manual weeding and it covered approximately 0.1 ha in an hour. The draft requirement of this implement on a sandy soil, while covering a 45 cm wide strip, was about 32 kg and its field capacity was about 0.1 ha/h.

Results obtained from data analysis across the locations (**Table 1**), indicate that there is no significant difference in draft requirement, work capacity, and weeding efficiency of the donkey-drawn cultivator and the Hoe Asine. The draft requirement of each implement (about 32 kg) was within the pulling capacity of the donkeys and there was no undue exertion to the animals. Some of the problems such as trash getting entangled with tines and larger pull required due to deeper penetratioin of tines or wider coverage were the same for both implements. In general, both implements are equally good for inter-row cultivation. However,

Table 1 Performance[1] of the Donkey-drawn Cultivator and Hoe Asine for Inter-row Cultivation, Mali, Rainy Season 1989

Implement	Draft (kg)	Width of cut (cm)	Work capacity (ha/h)	Depth of cut (cm)	Weeding efficiency[2] (%)
DDCI	32.5	51.33	0.11	6.78	86.2
Hoe Asine	31.1	51.00	0.11	6.38	83.0
SE	(±)1.18	(±)0.012	(±)0.014	(±)0.567	(±)2.00

1. Results are based on data from 3 locations in Mali. Differences in values of the performance parameters are statistically non-significant.
2. Weeding efficiency = [(No. of weeds before operation) − (No. of weeds after operation)]/(No. of weeds before operation).

Table 2 Performance of the Two-row Hill Seeder, Mali, Rainy Season 1989

Crop	Spacing between hills (cm)	No. of seeds per hill	Depth of sowing (cm)	Work capacity (ha/h)
Pearl millet	43.4	14.7	2.8	0.22
(Bodoni)	(3.55)[1]	(5.73)	(0.81)	(0.011)
Sorghum	42.2	4.9	3.2	0.21
(CMS 219)	(4.17)	(1.76)	(0.65)	(0.012)

1. Values of SE(±) are given in parantheses.

the new cultivator (cost: about US$ 95) is simple in construction, it can be fabricated with locally available material, and it is cheaper than the Hoe Asine.

Results obtained from field testing of the donkey-drawn two-row seeder indicate that it can be successfully used for sowing pearl millet and sorghum in hills (**Table 2**). The average spacing between two consecutive hills in each row was 42 cm and the number of seeds per hill were 15 for pearl millet and 5 for sorghum. Spacing between rows is adjustable up to 90 cm. The optimum size of opening for seed metering for pearl millet (Boboni) was 5 mm and for sorghum (CSM 219) it was 5.5 mm. The number of seeds per hill can be varied by setting different sizes of openings for the seed metering according to the size and quality of seeds.

In the final prototypes, the main frame, clamps and wheel have become common for both the seeder and cultivator. Therefore, the cultivator can be converted into a two-row seeder by removing the tines and fitting the components for seeder (i.e., furrow openers, seed container, etc.). Thus, the donkey-drawn implement can be used as a 3-tine cultivator and as a two-row seeder also. It is proposed to name this implement as the "Donkey-drawn Cultivator-cum-Seeder" (DDCS). The actual cost of the DDCS is approximately US$100.

Conclusion

The donkey-drawn cultivator-cum-seeder is an appropriate implement for small farmers in West African semi-arid tropics. It is simple in construction and can be fabricated with locally available material. It is cheaper than the existing donkey-drawn seeders and cultivators. Farmers can perform seeding and weeding operations faster with this implement compared to the manual operation and expand the area under cultivation.

Engineering drawings of the donkey-drawn cultivator-cum-seeder are available on request from The Director, Resource Management Program, ICRISAT.

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Design Aspects and Performance of An Axial-flow Vegetable Seed Extracting Machine

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Water Lifting Devices for Irrigation in Bangladesh

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Abstract

Bangladesh has a great potential of surface and underground water for irrigation. Only 16% of the total cultivable land is currently irrigated. Bringing in more land under irrigation project should improve the agricultural output of the country.

Both manual and power pumps are now extensively used for irrigation in Bangladesh. A survey on the economics of manual and power pumps has shown that the cost per hectare of irrigated land is at least 5 times for manual pumps than that of a low-lift pump when the labour costs are included. Samples of the power pumps are tested on the laboratory test bench for performance characteristics before being fielded. However, this performance test was not reproducible in the field because of different aquifer and well conditions. Sufficient field information is necessary to correlate the field performance and laboratory performance of the pump set system.

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Introduction

The population of Bangladesh is about 104 million in an area of 143 999 km^2 (55 598 sq. mile). About 61.3% of the population is engaged in agriculture. The cultivable land is approximately 122 955 km^2 (33.5 million acres) of which 53% is single cropped, 39% double cropped and 8% triple cropped. The economy of the country depends mainly on the agricultural output and this accounts for about 46% GDP. Since the cultivable land is limited, an increase in per hectare yield through intensive cultivation is the only alternative solution to meet the serious food deficit. The per hectare yield can be increased by using fertilizer, pesticide, mechanized cultivation, improved type of seeds and bringing more land under irrigation programme.

The water resources, both surface and underground, of Bangladesh has a great potential for irrigation use. From very early days, the farmers used various traditional irrigation methods such as swing busket, 'dhoon,' canals, etc. to irrigate their lands. These traditional methods are inefficient and have limitations, hence led to the development and use of other sources of irrigation methods. These alternative sources include improved manually operated pumps (No. 6, Rower, Treadle, Tara, Diapharagm etc.) and power pumps (STW, LLP, DTW, submersible pump). A recent statistics **(Table 1)** has reflected the increasing popularity of the alternative modern sources of irrigation over the traditional methods. **Figs. 1** and **2** trace the history of number of MOSTI (manually operated shallow tubewells for irrigation) and power pumps in operation in field for irrigation purposes. From the figures it appears that there was an increase on the use of MOSTI and power pumps (LLP, STW, DTW) up to 1985 and after 1980 there is a rapid increase in the use of STW. **Table 2** shows the number of pumps that are in use during 1986, the percentage that are out of operation and the usage of the pump's capacity. The unit command areas of STW and DTW are below 50% of its rated values and for LLP it is just above 50%. This may be due to improper operation of the prime mover, poor water management and transportation loss (canal loss) etc. The distribution of power pumps (STW, LLP, DTW) in use in Bangladesh is shown in **Fig. 12**. Again, a recent cost analysis indicates that the irrigation cost (Take/ha) of manually operated pumps (including labour cost) are at least 5 times higher than that of a LLP. The irrigation costs of four manually operated pumps and LLP are given in **Table 3**. This cost analysis provides an insight into the economics of irrigation and emphasizes the uses of power pumps.

The analysis confirms that proper management of irrigation methods and pumping equipments is as vital as hardware. A good pumping set is of no use unless it is properly managed, hence a systematic approach to train manpower in these areas is very important.

This paper presents a brief review and analysis of the performance characteristics of different manual and power pumps used in Bangladesh for irrigation purpose.

Table 1 Irrigated Areas Covered by Different Methods (1 000 ha)

Method	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86
Modern methods	1 033	1 130	1 340	1 356	1 739	1 721
Tubewells	227	277	421	682	899	963
Low-lift pumps	681	720	763	682	696	609
BWDB gravity schemes	125	133	156	172	145	149
Traditional methods	643	634	549	463	376	377
Swing basket	85	88	87	86	81	84
Dhoons	377	364	300	244	188	170
Canals	28	34	8	0	2	14
Others	153	148	154	133	105	109
Total net of which	1 676	1 764	1 889	1 999	2 115	2 098
Moderns (%)	61.6	64.1	71.0	76.8	82.2	82.0
Traditionals (%)	38.4	35.9	29.0	23.2	17.8	18.0

SOURCE: Bangladesh Adjustment in the Eighties and Short-Term Prospects, Volume II, Statistical Appendix, World Bank Report, March 10, 1988.

Description of Water Lifting Devices

The irrigation equipment which are commonly used in Bangladesh are:

(A) Manually operated pumps

(B) Power pumps:

(i) Shallow tube well

Table 2 Status of Irrigation Devices Fielded in 1986

Irrigation device	Total No.	% Out of operation	Unit command area (ha)	Rated command area (ha)
MOSTI	287 791	—	0.2	0.3
STW	155 763	8	3.2	8.0
LLP	36 174	12	17.1	30.0
DTW	19 748	15	17.5	40.0

MOSTI: Manually operated shallow tubewell for Irrigation. It includes No. 6, Rower, Treadle, Tara, Diaphragm pumps, etc.

SOURCE: A Study on Low Lift Pump Head in Bangladesh, 1977-78, BADC Publication, Dhaka.

Table 3 Estimated Irrigation Cost (TK/ha) of Different Irrigation Devices

Irrigation device	Total cost (TK/ha)	Cost (TK/ha) excluding labour cost
Diaphragm (BRRI) pump	9 582.40	1 716.00
Treadle pump	16 145.00	1 062.80
Rower pump	18 979.20	1 842.40
Swing basket	13 164.90	237.30
LLP	1 859.00	—

SOURCE: Md. Muzzammil Huq, et al. Annual Report on Evaluation and Extension of Different Mannual Pumps in the Farmer's Field, Agricultural Engineering Division, BRRI, 1988.

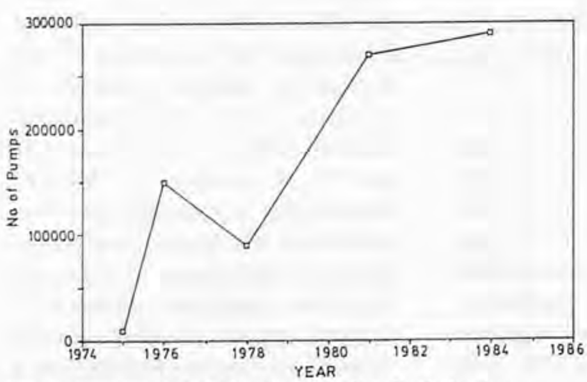


Fig. 1 Number of MOSTI in operation for irrigation.

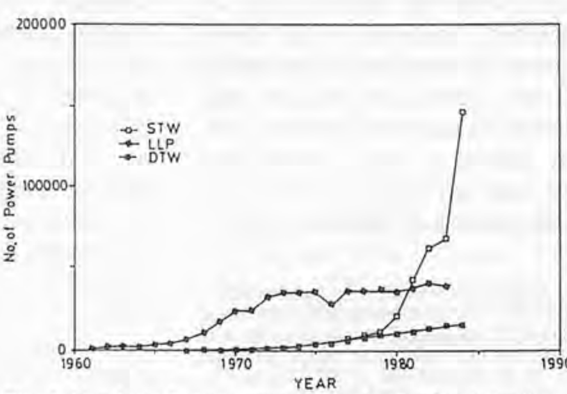


Fig. 2 Number of power pump in operation for irrigation.

(STW)
(ii) Low lift pump (LLP)
(iii) Deep tube well (DTW):
(a) Turbine pump
(b) Submersible pump

This classification of power pumps according to the capacity and head is shown in **Table 4**.

Manual Pumps

Different types of manual pumps are used in Bangladesh for lifting water. The hand tubewell (No. 6 pump), rower, treadle, tara, diaphragm etc. are designed for lifting water from shallow aquifer. These are suction type positive displacement pumps. The major head for these pumps is on the suction side and the delivery head is very small. The suction head includes all hydrodynamic and frictional losses and the static lift. However, from the viewpoint of cavitation, the static lift for these pumps should not exceed 8m and it depends upon the aquifer characteristics, installation and other factors.

The No. 6 pump is a reciprocating hand tubewell positive displacement pump. It is constructed almost entirely with cast iron. The plunger uses a moulded PVC or leather cup washer and has a cast iron seat valve. The check valve is a simple leather flap with a cast iron counter weight. A schematic diagram of this pump is shown in **Fig. 3**. This pump is operated by hand with a lever having a maximum lever arm ratio of about 4. The angular movement of the lever is within 100° and produces a stroke length of 24 cm. During the upward motion of the plunger, the check valve opens and the seat valve remains closed. Water enters the cylinder through the G.I. or PVC inlet pipe. As the plunger is pushed down, the check valve closes and the seat valve opens so that the water passes through the plunger and is accumulated above

Table 4 Classification of Power Pumps According to Capacity, Source of Water, Suction Head and Impeller Type

Type of pump	Discharge cusec (l/s)	Head suction ft (m)	Total ft (m)	No. of stages	Source of water
STW (centrifugal)	1/2 and 3/4 (14 and 21)	20 (6.1)	20 (6.1)	Single	Surface (river, pond, canal etc.)
LLP (centrifugal)	1 and 2 (28.3 and 56.6)	20 (6.1)	20 and 30 (6.1 and 9.1)	Single	Ground water
DTW (turbine and submersible)	2 (56.6)	—	50'-100' (15.2 and 30.5)	Multi	Ground water

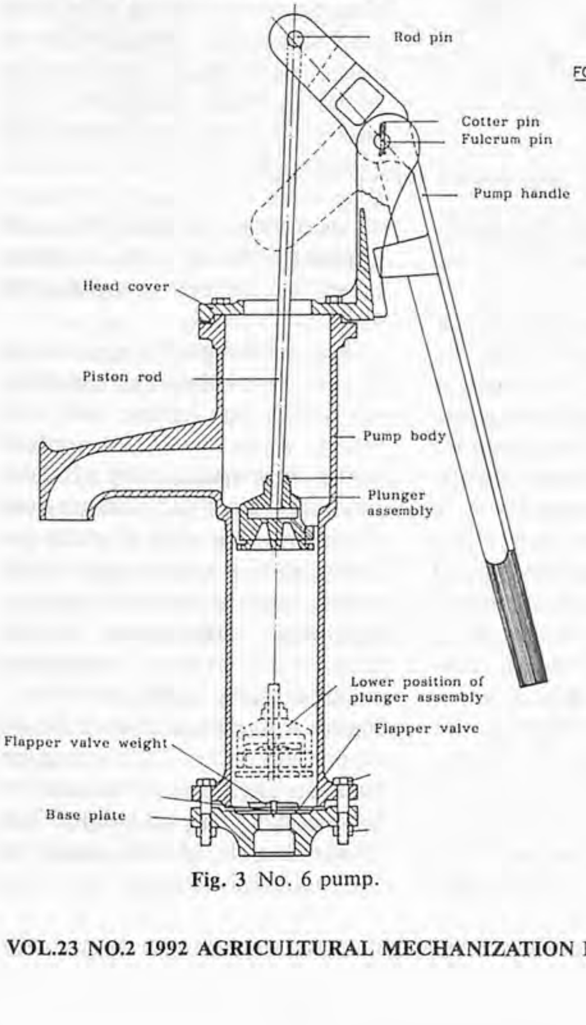


Fig. 3 No. 6 pump.

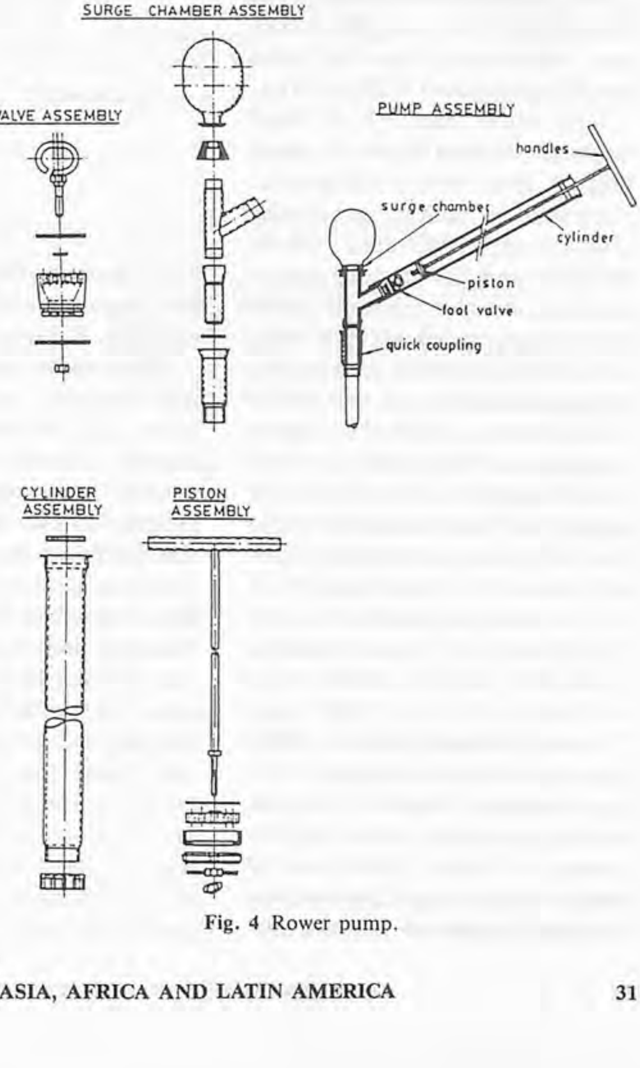


Fig. 4 Rower pump.

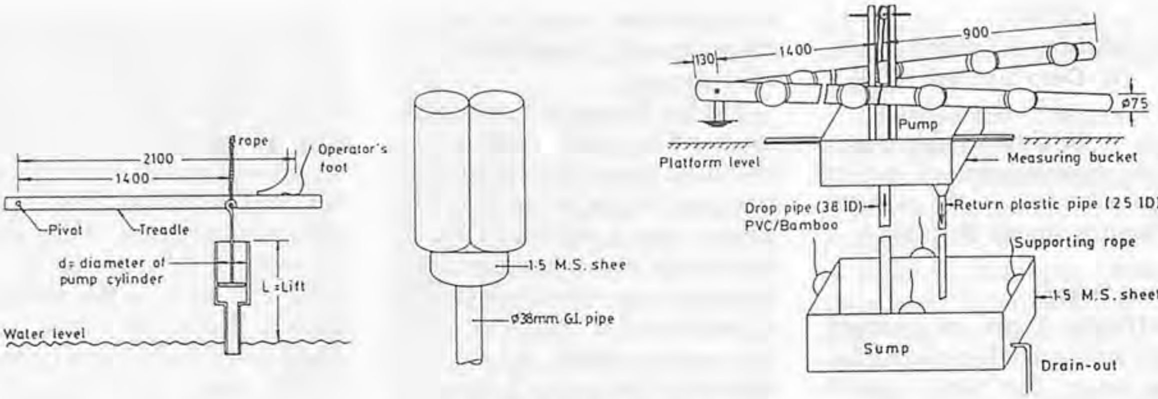
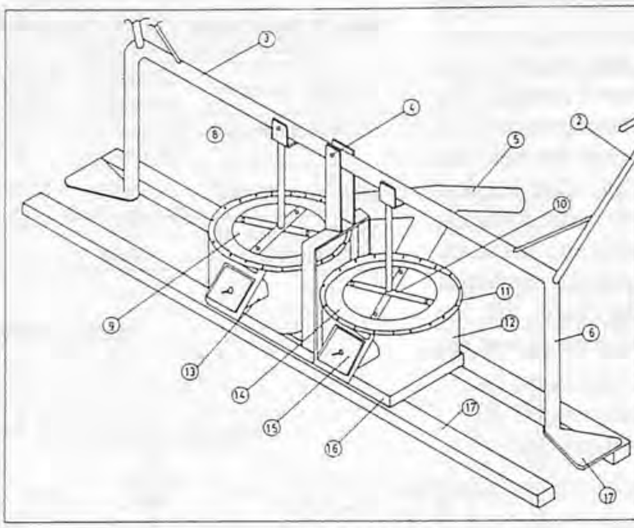


Fig. 5 Treadle pump.



SL	Name of the parts
1	Grip
2	Handle
3	Lever
4	Pin
5	Suction Manifold
6	Pedal
7	Footing
8	Lift Arm
9	Sandwitch Plate
10	Reinforcing Bar
11	Ring
12	Suction Chamber
13	Delivery Outlet
14	Diaphragm
15	Valve weight
16	Base Frame
17	Base

COMPONENT PARTS LIST

Fig. 6 BARI diaphragm pump.

it. This is discharged during the upward motion of the plunger. Thus the operation is single acting and the discharge is intermittent. The discharge depends upon the size of the cylinder, number of strokes per minute and head. A nominal discharge per stroke is about 1.4 litres of water while the cycle time of operation is approximately 2 sec. The pump has a suction head up to 8m. The total weight of the pump is about 30 kg.

The rower pump is a hand operated suction type of pump **(Fig. 4)**. It is used for lifting water from shallow aquifer. Its cylinder is an extruded PVC pipe, 5.08 cm diameter and 120 cm long and is mounted on the tubewell at 60 degree from horizontal. The plunger (piston assembly) uses an impregnated leather cup seal which is mounted on aluminium piston components. The check valve is a moulded plastic component with simple flap valve made of rubber disc and it does not need any counter weight. A non-return foot valve is placed at the lower end of the cylinder. A 16 cm diameter aluminum surge chamber is attached to the water inlet pipe. The surge chamber helps to reduce the inertial effect in the water inlet pipe enabling a relatively easy and smooth pumping effort and increases efficiency. The stroke length of this pump depends upon the physical size of the operator and is around 100 cm. The principle of operation is identical to that of a No. 6 pump.

The treadle pump **(Fig. 5)** is a foot-operated suction type of pump and is used for shallow aquifer. It has two cylinders made of steel sheet, a pair of aluminum piston and two bamboo pedals. The cylinders are about 9 cm in diameter and 30 cm long. The stroke length is about 26 cm and the cycle time is approximately 1 sec. It can produce a suction head up to 5.5 m. The piston has a rubber flap valve and a non-return foot valve that is fitted at the bottom of the cylinder. The 2.3 m-long bamboo pedals are linked to the piston rods by a pin. Water is discharged through the upper free end of the cylinders. The principle of operation of this pump is similar to that of a No. 6 pump except that the lever is operated by foot.

The diaphragm pump consists of a circular rubber diaphragm fitted over a box having inlet and outlet ports with non-return valves. It is operated by a handle fitted on a stand and actuates over a fulcrum. One man operates the pump with a long handle which raises and lowers the rubber diaphragm. Movement of the diaphragm creates necessary suction and delivery head. **Figure 6** shows a twin cylinder diaphragm pump. The rectangular cylinders are 28 cm × 28 cm at the base and 24 cm in height. The stroke length of this pump is approximately 8 cm.

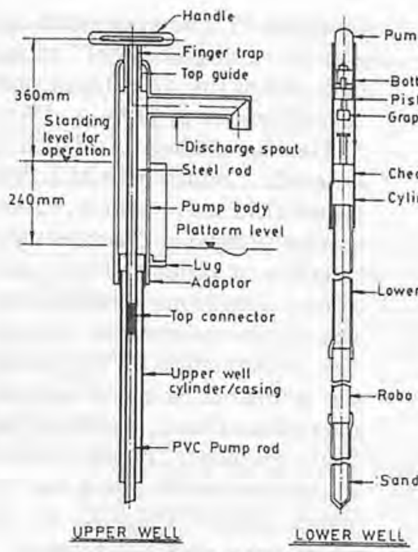


Fig. 7 TARA pump.

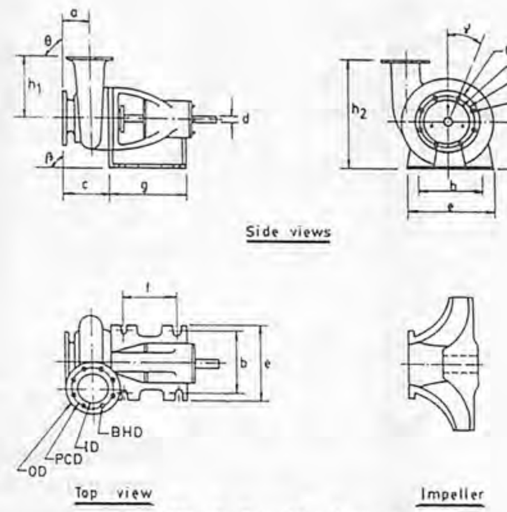


Fig. 8 Centrifugal pump.

The tara pump has been developed for lifting water from deep aquifer. The principle of operation of this pump is similar to that of a No. 6 pump with modifications of piston actuating rod. A 42-mm outer diameter PVC pipe is used as a piston rod in a 54 mm diameter PVC cylinder. The length of the piston rod is designed according to the level of the aquifer. This is a hand operated pump and has a stroke length of about 30 cm and a cycle time of approximately 1 sec. A schematic diagram of this pump is shown in **Fig. 7**.

The current prices of some of these manually operated pumps are listed in **Table 5**.

Table 5 Current Price of Different Water Lifting Devices

Item	Type of pump	Capacity	Price Taka/unit
Manually operated pump*	Diaphram (BRRI)	248 l/min	2 500.00
	Rower	58 l/min	550.00
	Treadle	65 l/min	550.00
	Swing Basket	227 l/min	70.00
Power pump**	STW + 9 hp Diesel engine	3/4 cusec	22 650.00
	LLP + 9 hp Diesel engine	1 cusec	25 000.00
	LLP + 16 hp Diesel engine	2 cusec	46 000.00
	DTW + 31.5 hp Diesel engine	2 cusec (100' head)	129 000.00
	Submersible pump + motor	2 cusec	85 000.00

SOURCES: Op. cit.
* Price at 1983-84 level, **[12] 1 cusec = 32.28 l/s, 1 ft = 0.304 m, Taka 33.83 = 1 US$.

Table 6 Local Manufactures of Pumps and Their Prime Movers.

Pump and prime movers	Manufacturers
Centrifugal pump	Milners (KSB), Farmland, BMTF, Shahparan Engineering Works, Mohammadi Engineering Works, Janata Machine Tools, etc.
Turbine pump	Milners, Farmland, Sonar Bangla, BMTF, etc.
Diesel engine	Bangladesh Diesel Plant
Electric motor	General Electric Company.

LLP and STW

In the LLP and STW irrigation areas in Bangladesh the following types of rotodynamic pumps (centrifugal) are in use (**Fig. 8**):

i) Radial flow, single suction, closed type impeller and single stage; and

ii) Mixed flow, single suction, closed type impeller and single stage.

The LLP is commonly used for river and canal pumping and the STW is used for ground water lifting. The capacity and head of these pumps are shown in **Table 4**. The pump is coupled to an engine or electric motor and is fixed on a permanent foundation. Engine-operated pumping sets may be installed on a trolley and can be used as a portable unit. When installed on a permanent foundation the suction and delivery pipes are made of rigid pipes which are supported on ports at suitable points. The pump should be installed in such a way that it is always above the water surface, but as close to it as possible to reduce the losses. Most of the LLPs operate under a head of 20 ft (6.1 m) or less and at discharge of maximum 2 cusec (56.6 l/s) and they are manufactured locally. A list of local manufacturers of this pump is given in **Table 6** and the current prices of these pumps with prime movers are listed in **Table 5**.

DTW and Submersible Pump

A vertical turbine pump also called a deepwell turbine pump (**Fig. 9**), is a vertical axis centrifugal or mixed flow type pump comprising of stages which accomodate rotating impellers

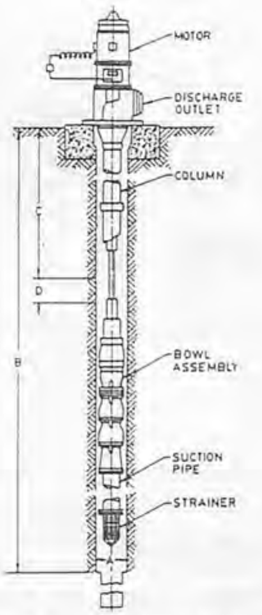


Fig. 9 Deepwell turbine pump.

and stationary bowls possessing guide vanes. Turbine pumps are specially adapted to tube wells where pumping water level is below the practical limits of a volute centrifugal pump. These pumps are used for high lifts and have high efficiencies under optimum operating conditions.

A vertical turbine pump close to a small diameter submersible electric motor is termed as submersible pump **(Fig. 10)**. The motor is connected directly below the intake of the pump. The pump element and the motor operate entirely submerged. Such an installation eliminates the long vertical shaft in the column pipe. The operating and maintenance costs are less than that of a turbine pump. But due to the lack of skilled operators, this pump has not gained popularity for irrigation purposes (only about 700 submersible pumps were fielded through Bangladesh Agricultural Development Corporation (BADC) up to 1983-84. After this period no other submersible pump has been produced).

The turbine pump up to 2 cusec (56.6 l/s) capacity and the prime

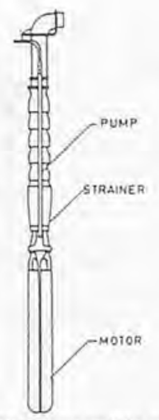


Fig. 10 Submersible pump.

movers (diesel engine and electric motors) are manufactured locally. **Table 6** lists a few names of such local manufacturers. (Submersible pumps are not manufactured yet in Bangladesh)

Performance Characteristics

Manually Operated Pumps

Some laboratory test data by the Consumer's Association Testing and Research Laboratory, U.K. provided some test results for No. 6 pump and power pumps [7] **(Table 7)**. These test results are given for a single head of 7 m and both pumps run with almost similar efficiencies of 60% + 5%.

The Bangladesh Agricultural Research Council (BARC) conducted field tests of No. 6, rower, treadle pumps at 27 sites in 7 locations of varied soil and agro-climatic conditions in Bangladesh. The results are given in **Table 8**. The performance of the pumps was compared based on the average values of head, discharge and stroke frequency. It was concluded that the treadle pump had the highest output followed by the rower pump and No. 6 pump.

Baumann and Fuller made a critical evaluation of various manual pumps used for irrigation in Bangladesh. The performance characteristics of No. 6, rower, treadle and tara pump by Baumann and Fuller are given in **Table 9**.

This evaluation shows that No. 6 pump produces 0.56-0.69 l/s at 1-8 m head while the tara pump discharges the same quantity of water at 16 m head. The treadle

Table 7 Performance of No. 6 and Rower Pumps

Type	Head (m)	Strokes/min	Discharge (l/s)	Efficiency
No. 6	7	20	0.43	59%
	7	30	0.60	67%
	7	40	0.86	65%
Rower pump with surge tank	7	11	0.30	66%
	7	15	0.45	64%
	7	19	0.54	65%
Rower pump without surge tank	7	11	0.30	62%
	7	14	0.40	59%
	7	19	0.54	56%

Table 8 Field Performance of Different Pumps

Locations	No. 6 Pump			Rower Pump			Treadle Pump		
	Head (m)	Capacity (l/min)	Stroke (per min)	Head (m)	Capacity (l/min)	Stroke (per min)	Head (m)	Capacity (l/min)	Stroke (per min)
Hathazari	3.53	25.84	25	3.56	33.22	25	3.56	32.08	40
Feni	2.99	41.06	33	3.56	39.61	28	3.49	36.12	45
Rangpur	3.09	30.31	33	3.08	31.14	30	3.12	35.88	35
Jessore	3.84	18.63	32	3.97	22.56	24	3.83	46.49	43
Rajshahi	6.55	14.98	25	6.13	22.60	22	6.15	36.10	36
Thakurgaon	2.20	36.00	32	3.75	25.55	24	3.58	38.50	36
Jamalpur	6.39	16.11	24	6.56	19.67	22	6.58	34.88	34
Bogra	5.35	24.28	28	5.36	31.22	25	5.35	34.35	32
Comilla	7.21	14.66	25	7.17	18.75	20	7.22	33.05	29

SOURCE: "Review of Hand Tubewells Literature and Some Recommendations regarding Rower, Treadle, No. 6 and Tara Pumps for Irrigation in Bangladesh", Report of Mechanical Engineering Dept., BUET, Dhaka 1986.

Table 9 Characteristics of Different Manual Pumps

Pump type	Well diameter (cm)	Lift (m)	Strokes/min	Discharge litre/sec
No. 6	3.8	1-8	30	0.56-0.60
Treadle	4.5	1-5.3	30	0..97-1.11
Rower	3.81	1-8.5	30	0.69-0.83
Tara	3.81	16	30	0.56-9.69

Table 10 Command Area of Different Manually Operated Pumps

Pump	Command area (acre) under a head of		
	1.5 m	3.0 m	4.6 m
BRRI diaphragm pump	2.62	1.69	1.31
No. 6 pump	0.3	0.49	0.51
Rower pump	0.7	0.50	0.51
Treadle pump	1.4	1.20	0.57

SOURCE: Md. Abdul Gani and Humayun Kabir Khandakar, "Collection on Different Types of Manually Operated Pumps Available in the Country and Evaluation of Their Performance in Order to Carry Further Modification if Necessary to Improve Performance", July 1983, BARC, Dhaka.

Table 11 BADC Specifications for Power Pumps

Item	LLP	STW	DTW
Head (ft)	20-30	20	50-100
Discharge (cfs)	2 and 1	1/2 and 3/4	2
Efficiency	70%	70%	80%
RPM	2 200/1 500	2 200/1 000	1 500
Horsepower	10 for 1 cfs 20 for 2 cfs	3.5-8	20-31.5
Type of drive	DE and EM*	DE and EM	DE and EM
Suction head (m)	6.1	6.1	—
Delivery dia (cm)	12.5-15	10	15-20.3

* DE — Diesel Engine, EM — Electric Motor.
1 cfs = 32.28 l/s.

Table 12 BADC Specification for Diesel Engines

Item	LLP	STW	DTW
Engine hp	10 and 16	5 and 7	22.5 and 31.5
Max fuel consumption (g/Bhp/h)	220	192-210	—
RPM	2 200/1 500	2 200/1 500	1 500
Lubricating oil	SAE 30	SAE 30	SAE 30 and 40

pump has the highest discharge but the range of operating head is the lowest.

From the above analysis it is evident that no unified parameters exists to compare the performance of different types of manual pumps.

Considering the command area (acre) the BRRI diaphragm pump appears to be the most promising water lifting device (**Table 10**) at 1.5 m and 3 m heads. But at more than 3.0 m head, Gani and Khondokar recommend the use of the rower pump for its low operating cost and power requirement.

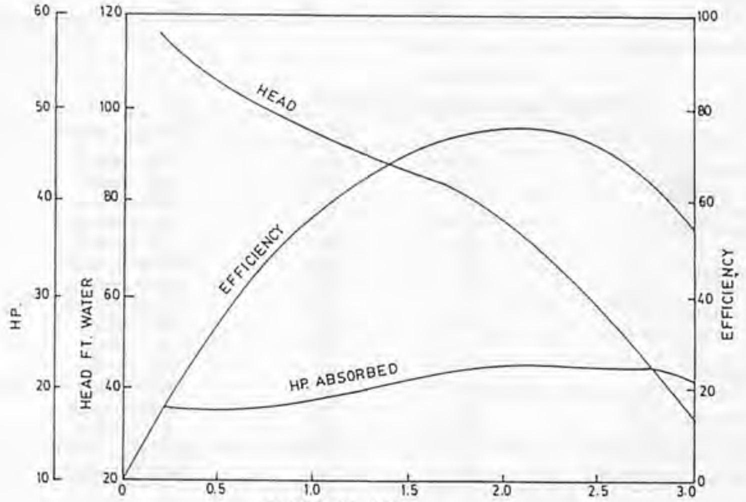


Fig. 11 Characteristics of turbine pump.

Power Pumps

The specifications of the power pumps and their drive systems have been made standard and the laboratory (bench) test performance characteristics are used to select the pump as per requirement. The BADC specifications for the power pumps and diesel engines are cited in **Tables 11** and **12**. Pump test bench facilities are available at BUET, BMTF, BADC and with some manufacturers. The pump set may operate in the field in a condition different from that of the laboratory as a result of which the performance may vary. This will occur if the pump is subjected to a head and load which are different from optimum condition.

Figure 11 shows a typical laboratory characteristics curve of a turbine pump. If the available head together with losses in strainer and pipe deviates much from the design condition the efficiency of the pump goes down. if the head in the fields is too high, then the discharge will be less and consumes more energy. The head depends on the local aquifer level and it has a great impact on the performance. To illustrate this fact, a typical field performance of a DTW irrigatioin by using the identical set of turbine pumps at different locations within a radius of 8 km is shown in **Table 13**. The results show a loss of discharge 20% to 56% of the rated value. The efficiency also comes down to about 44% which is too low for this type of turbine pump. The variation of pumping water head at these stations is within 1 m. The precise characteristics of the aquifer at these stations are unknown. The large deviation in the performance of the turbine pump is mainlly due to the combined effect of the aquifer and the

Table 13 Field Performance of Turbine Pumps of Designed Capacity 57 l/s and Efficiency 80% at Joydevpur Zone

Station	Pump speed (rpm)	Fuel consumption (l/h)	Stationary water table (m)	Pumping water table (m)	Discharge (l/s)	Efficiency (%)
Naojur	1 780	4.45	12.62	18.81	45.02	78.9
Ituhata	1 845	4.13	13.65	17.17	28.9	50.67
Palerpara	1 862	4.02	10.2	18.05	45.9	82.2
Bogra	—	4.13	12.34	17.22	36.02	63.5
Jugitola	1 920	4.54	13.45	18.89	25.27	44.3

Length of pump housing: 24.38 m.
Length of strainer: 30-36 m.
Source: BADC, Joydevpur.

Table 14 Total Head for Low Lift Pump

Region	Maximum head ft (m)	Percentage of head in range			
		0-10	10-20	20-30	30-40
Rajshahi	39.11 (11.9)	1	32	44	23
Bogra	49.65 (15.1)	—	18	76	5
Dinajpur	34.35 (10.5)	—	40	6	—
Barisal	28.29 (8.6)	1	93	6	—
Sylhet	59.8 (18.2)	1	42	51	5
Mymensingh	58.15 (17.7)	1	27	45	18
Faridpur	37.54 (11.4)	1	50	44	5
Dhaka	46.47 (14.1)	0.78	42	41	7

Source: Op. cit.

Table 15 List of Diesel Engines Used in Irrigation

Name and Model	HP	RPM	Cooling System
Ruston 1YWA	8.8	1 500	Air-cooled
Ruston 2YWA	17.6	1 500	Air-cooled
Deutz F2L912	16	1 500	Air-cooled
Deutz F2L912	18	1 500	Air-cooled
Deutz F2L910D	9	2 200	Air-cooled
Yanmar TS105C	9	2 200	Water-cooled
Yanmar TS180C	15	2 200	Water-cooled
Yanmar TS220C	18	2 200	Water-cooled
Mitsubishi M-110	9.5	2 200	Air-cooled
Lister HR-4	4.5	1 500	Air-cooled
Lister ST-2	28	2 200	Air-cooled
Slavia 1ST120	14	1 500	Air-cooled
Daedong ND30	8	2 200	Water-cooled
Kirlosker RS-2	6.25	1 500	Air-cooled
Kubota ER900-N	9	2 200	Water-cooled
Kubota ER2200-N	18	2 200	Water-cooled

head. A similar deviation is also observable in the case of STW.

The low lift pump irrigation is also in use in many areas of Bangladesh. The pumps as per specification in **Table 11** are recommended. For this method of irrigation the pumping head varies from region to region. Some findings of BADC study [9] on LLP showing maximum available head are given in **Table 14**. It is evident that the head variation is quite large from region to region which is why the application of an identical brand of LLP at different regions shows similar deviation of the field performance as given in **Table 13**. The available source and head of the water table should be considered in selecting the type of pump for a given field condition.

Prime Movers

Most power pumps are driven by diesel engines. Some of the engines are locally manufactured and assembled. Their field performance, maintenance, spare parts requirement, etc. are not being regularly monitored. **Table 15** lists various models of diesel engines that are now in use in Bangladesh for irrigation. The laboratory test results show the SFC for the engines vary from 170 to 220 gpm/Bhp/h for various models.

Conclusions

The following conclusions are drawn from the above presentation:

i) Bangladesh has a great potential for irrigation to meet the huge food deficit in the country. Only 16% of the cultivable land is currently irrigated. Large land areas need to be served by irrigation schemes to improve crop production.

ii) Modern manually-operated and power pumps are fast replacing the traditional pumps, the manually-operated modern pumps, particularly No. 6 pumps.

iii) A comparison of irrigation cost of different manually operated pumps with LLP shows that LLP is cheaper.

iv) The manually-operated pumps as well as the power pumps are now manufactured in the country. The performance characteristics of the power pumps (LLP, STW, DTW) have attained up to the standard set by the National Standardization Committee. It is important to generate field performance data for these pumps and attempts should be made to correlate the laboratory performance data and field performance characteristics of these pumps.

v) Available information on the field performance of the prime movers (diesel engines and electric motors) is insufficient.

vi) Attempt should be made to develop a mathematical tool to compare the performance of different manually operated pumps as regards their output, energy input, design specification and cost.

vii) Training of the farmers (pump users) should be organized into some form of cooperatives so that they can look after the water

Fig. 12 Distribution of power pumps in Bangladesh.

pumping system.

viii) Information materials should be supplied to the farmers free of cost regarding water pumping system, irrigation methods and management.

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A Vining Machine for a Farm Level Green Pea Processing System in Northern Thailand

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Abstract

A simple pea vining machine was designed and developed as a component to a farm level post harvest pea processing system. The vining machine consisted of a beating drum and an inclined shaker as a separation system. Tests conducted on the machine indicated that a machine performance of 4 kg/h vining capacity, 99% efficiency and 2% pea damage was obtained at a drum speed of 200 rpm and a concave clearance of 7 mm. A 20 degree angle of the inclined shaker resulted in a maximum pea separation of 97%.

Introduction

An estimated 2 500 ha of green pea (Pisum sativum. L) are grown in the Northern and North Eastern Thailand, where approximately 5 000 tons of pea pods are produced. Most of the peas produced are sold commercially as fresh vegetables, while processing is neglibigle. Currently, new high yielding cultivar with improved agronomic characters are being developed to increase the total yield of green pea in the market.

With the anticipated increases in yield, methods will be needed for handling and processing the excess produciton at minimum cost to village level processors. The excess production obtained during the short harvesting period has to be handled and moved out of the farm area in the quickest possible time. Alternately, a village level processing, preservation and distribution system may prove beneficial to handle the excess production.

A village level processing system would include the development of a vining and dehydrating technique of limited cost. Dehydration is proposed since it is a low cost preservation technique at the village level and also reduces cost of packing, storing and transportation by reduced weight and volume of the final product. A simple processing system which could vine and dehydrate the peas would give farmers the capability of preserving their excess production and selling it during the off season.

The overall objective of the main study is to develop a village scale processing system for green peas which includes a vining or podding machine and a dehydration process that is capable of handling the excess production of farmers. To achieve this overall objective this study concentrated on the design and development of a vining mechanism that could be used as a component to the total system. The pea vining mechanism designed and developed in this study was tested for optimum vining capacity, separating capacity and efficiency and minimum damage to the peas.

Literature Review

Very little information is available on small scale vining mechanisms. Reports are, however, available on a traditional pea viner by Cargill and Rossmiller (1969) in which a hexagoual open ended drum was rotated on an oblong frame. The sides of the drum were covered by perforated mats or screens. A beater mechanism rotated within the drum. The speed of the outer drum is low while that of the inner beater is higher. This causes the pea pods to be picked up by the bars and ribs on the inside of the drum, then be carried upward and dropped again and again through the rapidly revolving beaters on the inside drums.

Methodology

The design and fabrication of the pea vining machine consisted

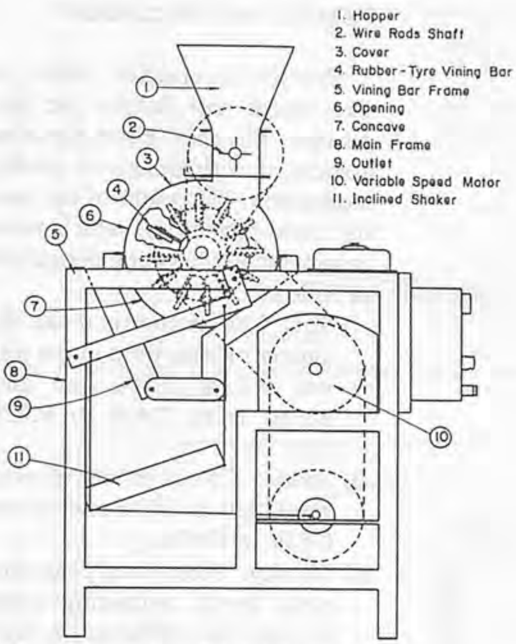

Fig. 1 The design of the vining machine.

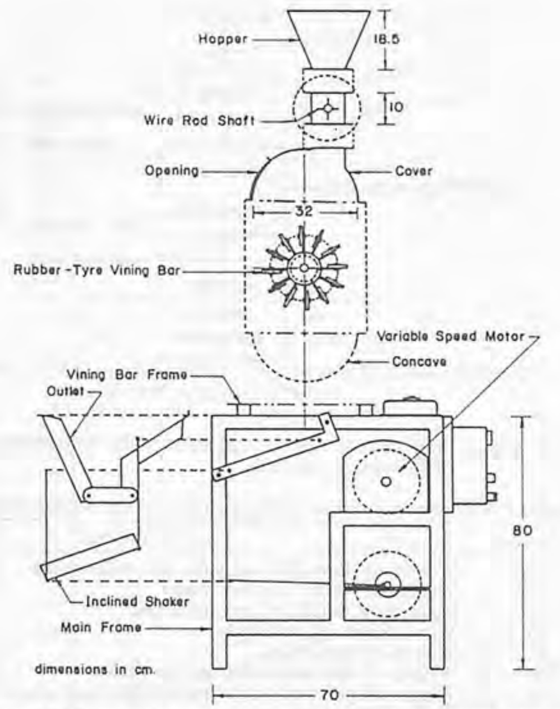

Fig. 2 Three main components of the viner the feeder, vining bar and inclined shaker.

of three main components namely the feeder vining drum with vining bars and an inclined shaker. **Figures 1** and **2** provide details of the different components of the vining machine. **Figure 3** illustrates the fabricated machine that was used for testing.

The feeder was installed on the top of the vining bar housing. It consisted of a hopper and a rotating feed roller shaft to which ten 0.5 × 2.0 cm steel rods were welded along its axis. Each steel rod was placed 90 degrees apart and arranged alternately. The constant rotation speed of the shaft gave a continuous metered flow of pea pods from the hopper to the vining drum.

The beaters were made of readily available used rubber tyre strips. These were selected for their low cost and also to limit the percentage of damaged peas. The dimensions of the vining bars were 11.5 cm long and 6 cm wide. The vining bars consisted of 12 sets of 26 cm long × 10 cm wide rubber tyre shoes fixed on two frames. A clearance was left for pods to rearrange themself so as to reduce damage. The concave clearance was adjustable and could be varied by raising or lowering the vining bar frame. One end of the vining bar frame was pivoted to the main frame. Wire mesh, selected to suit the size of peas was used in the concave. At one end of the vining drum an opening was made to separate pieces of pods that were bigger than the wire mesh. This opening was also found to increase the separating efficiency of the shaker.

An inclined shaker was installed below the concave in order to separate the small pieces of pods and impurities from peas, after the mixture of these materials leave the concave. The shaker was 30 × 34 × 5 cm in dimension. The angle of inclination of the shaker was adjustable and could be varied by turning it along a slotted arm.

The performance tests of the vining machine consisted of tests conducted on the vining and separating mechanism. In the tests

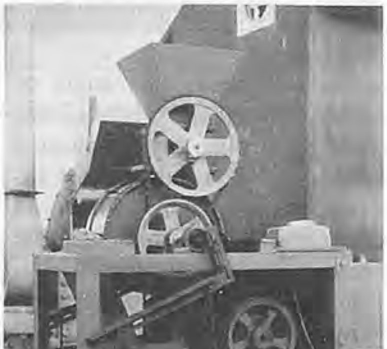

Fig. 3 The fabricated machine used for testing.

performed on the vining mechanism, the vining bar and inclined shaker were operated by a variable speed motor. In the tests performed on the separating mechanism, the speed of the vining bar and the shaker were fixed and the mechanism operated

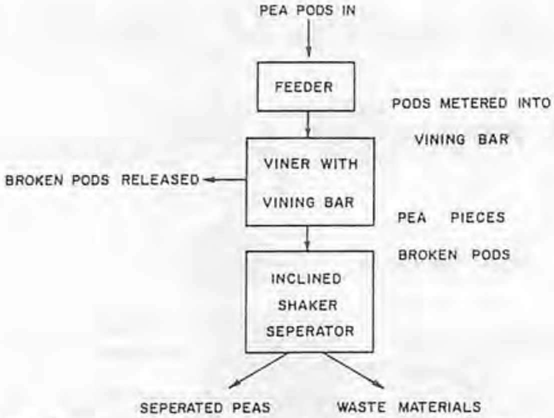

Fig. 4 Flow of material through three main components of the vining machine.

Table 1 Parameters Used in the Evaluation of the Vining Machine

Symbol	Definitions	
Wd	Weight of damaged and split pea seeds vined	(g)
Ww	Weight of whole pea sees vined	(g)
Ew	Equivalent weight of pea seeds fed	(g)
Wt	Total weight of pea seeds	(g)
Wi	Weight of impurities	(g)
Wr	Weight of pea seeds retained on shaker	(g)
Ws	Weight of pea seeds after passing through shaker	(g)
t	Vining time	(h)
Pd	Percentage of damage (%) [= Wd/Wt × 100]	
Ve	Vining Efficiency (%) [= (Ww + Wd)/Ew × 100]	
Vc	Vining Capacity (kg/h) [= (Ww + Wd)/t]	
Se	Separating Efficiency (%) [= Ws/(Ws + Wi) × 100]	
Pw	Percentage of Whole Seed (%) [= Ww/Wt × 100]	

under one speed. The angle of inclination of the shaker was varied by turning the tray along a slotted arm. The end of the shaker tray was covered by a wire mesh screen and was used to separate pieces of pods from peas.

In order to evaluate the performance of the vining bar mechanism, changes in rotation speed of the vining bar (vining bar velocity) were 160, 180, 200 and 220 rpm and concave clearance were 5, 7, 9 and 11 mm.

The vining tests were done with 300 g of pea pods. A vining time for this quantity was initially determined. After vining, all pea samples were gathered and measured to be classified in terms of damage, etc.

In order to evaluate the performance of the separating mechanism, changes in the angle of inclination of the shaker were taken as 15, 20 and 25 degrees. After the shaking operation for separation, all samples were gathered and measured to evaluate the separating efficiency. The flow of material through the three main components of the vining machine are shown in **Fig. 4**. **Table 1** gives details of the parameters used to test the efficiency of the vining system.

Results and Discussion

Physical properties, such as size, shape and density are important physical characteristics associated with design of vining mechanism. The results of the tests for these properties, which were considered in the vining design are as follows.

i) Size: The geometric mean diameter of peas used in the test was 8.2 ± .0303 mm and varied from 7.490 to 9.028 mm.
ii) Shape: The sphericity of peas was 0.920 ± 0.016 and varied 0.889 to 0.971.
iii) Density: Peas (vined peas) and pods (pods remaining after vining) were different in density. The density of peas is slightly higher than that for pods. The density of peas was 1.0731 ± 0.0139 g/cc while the density of pods was 1.0052 ± 0.0164 g/cc.

In testing the vining performance, four different vining bar speeds and concave clearances were used. A single revolution per minute of the vining bar was equivalent to 0.817 m/s of peripheral speed. With the increase in vining bar speed, the peripheral velocity also increased and the performance of the vining bar at these different speeds is

Table 2 Vining Performance of the Vining Machine at Different Vining Bar Speeds and Clearances

Vining bar speed rpm	Clearance (mm)	Percentage of damage (%)	Vining Efficiency (%)	Capacity (kg/h)	Percentage of whole pea (%)
160	5	10.64	99.40	3.291	88.76
	7	0.92	99.15	2.772	98.23
	9	0.53	97.82	2.017	97.25
	11	0.18	97.38	1.612	97.20
180	5	12.38	99.61	4.371	87.22
	7	1.41	99.23	3.517	97.82
	9	0.91	97.98	2.411	96.97
	11	0.45	97.69	2.095	97.26
200	5	14.57	99.74	5.036	85.17
	7	1.92	99.26	3.802	97.34
	9	1.40	98.94	3.426	97.50
	11	0.66	98.35	2.613	97.68
220	5	16.10	99.81	5.318	83.71
	7	3.04	99.50	4.616	96.29
	9	1.70	99.12	4.180	97.37
	11	0.87	98.61	3.079	97.75

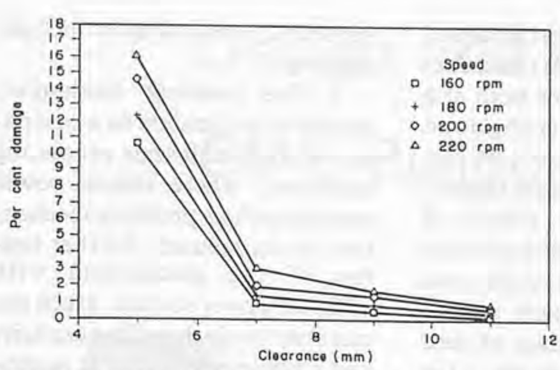

Fig. 5 Percentage of damage for different concave clearances and speeds.

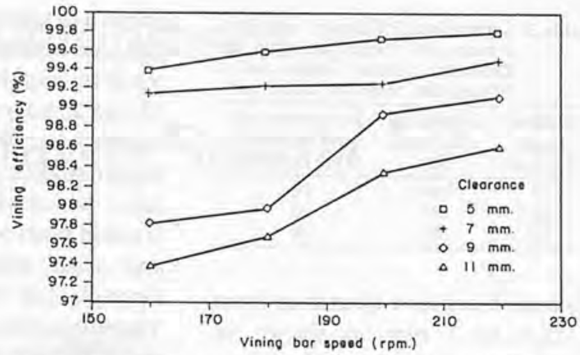

Fig. 7 The vining efficiency of the machine for different speeds and concave clearances.

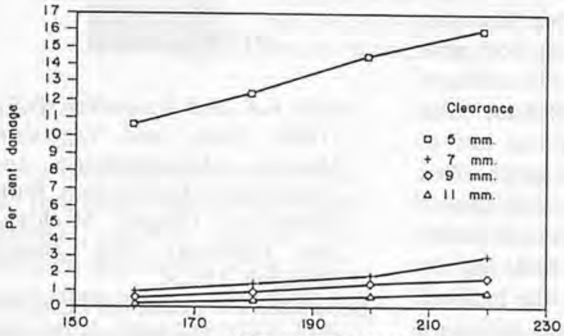

Fig. 6 Percentage of damage for different speeds and concave clearances.

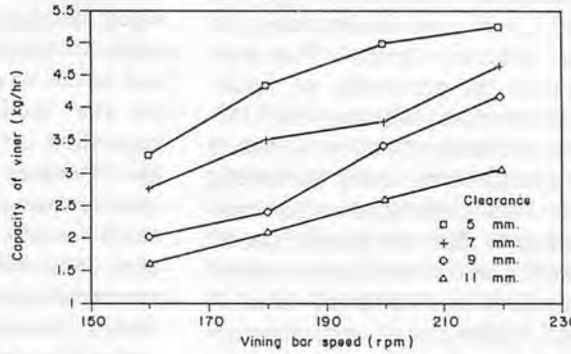

Fig. 8 The capacity of the vining machine for different speeds and concave clearances.

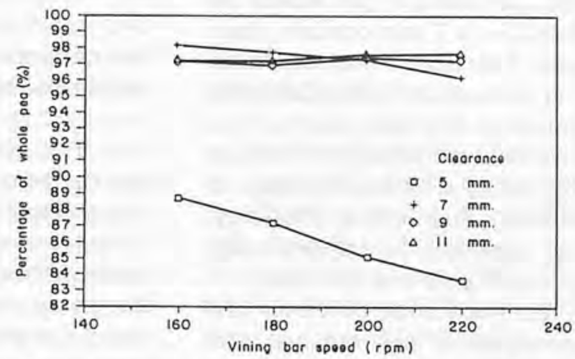

Fig. 9 Percentage of whole peas for different speeds and concave clearances.

given in **Table 2**.

Table 2, **Fig. 5** and **Fig. 6** illustrate the percentage of damage for different concave clearance and speeds of the vining bar. The results indicate that the damage decreased rapidly at each speed as the concave clearance was increased from 5 mm to 7 mm. With the clearance at 5 mm, the damage is greater than 10% by weight for all tested speeds. The damage also gradually increased if the vining bar speed increased from 160 rpm to 220 rpm for all clearances of the concave.

The vining efficiency in terms of whole and damaged peas increased with increased vining bar speeds, **Table 2** and **Fig. 7**. The lower concave clearances resulted in a higher vining efficiency. As the clearance was increased, the vining efficiency gradually decreased. The vining bar speed and concave clearance significantly affected the vining efficiency at a 5% significance level. The lowering of the concave clearance resulted in increased crushing and damage to peas while being released from the pods.

The capacity of the vining machine in terms of whole and damaged peas increased with an increase of vining bar speed but decreased with an increase in the concave clearance as shown in **Table 2** and **Fig. 8**. The maximum capacity of about 5.3 kg/h of green peas was observed at a 5 mm concave clearance and 220 rpm, vining bar speed. The vining bar speed and concave clearance significantly affected the capacity at 5% significance level. The capacity increased with an increased vining efficiency due to a decrease in the concave clearance.

The percentage of whole peas (measured as good peas vined) decreased with an increase of vining bar speed but increased with

Table 3 Separating Efficiency and Percentage of Seed Removal at Different Shaker Angles and a Vining Bar Speed of 200 rpm.

Shaker angle (Degree)	Separating efficiency (%)	Percentage of seed removal after shaking
15	99	92
20	97	97
25	96	90

increased concave clearance from 5 mm to 7 mm as shown in **Table 2** and **Fig. 9**. However, there was no difference in percentage of whole peas in the 9 mm and 11 mm concave clearances for the different speeds. This was because the percentage of whole peas increased slightly from 160 rpm to 200 rpm and was constant up to a 220 rpm vining bar speed. The Duncan-Multiple range test indicated that the percentage of whole peas at a 5 mm concave clearance was different from 7 mm, 9 mm and 11 mm concave clearance. There was a difference in the percentage of whole peas at 160 rpm and 220 rpm vining bar speed for a 7 mm concave clearance. Therefore it was considered that the optimum vining bar speed should be 200 rpm, and the concave clearance should be 7 mm. At this setting a lower percentage of damage, high vining efficiency, high capacity and high percentage of whole peas was obtained.

The separating efficiency and percentage of seed removal after shaking were tested by varying the angle of the shaker and fixing the vining bar speed at 200 rpm. The separating efficiency decreased with the increase of shaker angle from 15 degree to 25 degree (**Table 3**). The maximum separating efficiency was 99% at a 15 degree angle. However, the percentage of pea seed separated into the collector after shaking is low both at a 15 and 25 degree shaker angle and highest at 20 degrees. At the higher shaker angle more impurities, which include pieces of crushed pods roll down the shaker and small pieces of pods pass through the wire mesh screen. Therefore the percentage of seed removal decreased. On the other hand, the percentage of seed removal at a 15 degree angle is low since the angle is lower than the angle of repose, causing both peas and pieces of pods to be retained on the inclined shaker. The separating efficiency was low at the 25 degree shaker angle. This was because a too high shaker angle caused both peas and pieces of pods to roll down and clog the wire mesh screen on the inclined shaker. Therefore the optimum shaker angle was considered to be 20 degrees.

Conclusions and Recommendations

1. The vining tests indicated that the best performance of the vining machine was achieved at a 7 mm clearance and vining bar speed of 200 rpm. At these settings the vining capacity, vining efficiency and percentage of damage were 4 kg (seed) /h, 99% and 2%, respectively.

2. In the separation tests, the optimum setting for the separating mechanism of the vining and podding machine was found to be 20 degrees which gave 97% separating efficiency and 98% seed removal after inclined shaking.

3. The podding mechanism proved to be feasible as a component to the small scale processing operation, where simple power sources such as peddling mechanisms could be used. Further testing of the mechanism with different power sources, green pea maturity levels, handling capacity and cost determination is recommended.

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Design and Development of CIAE Bullock-drawn Reaper

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Abstract

An oxen-drawn harvester was the long-felt need of the Indian farmers. CIAE, Bhopal has designed and developed a simple and rugged oxen-drawn reaper for harvesting crops as cereals, pulses and oil seed. This is a light weight machine that requires less draft as compared to earlier designs of bullock-drawn reapers. The crops harvested by this machine is delivered in uniform bunches behind the cutter-bar. The special feature of this machine is transformation of low soil thrust developed from the traction wheel into higher force for cutting crops through crank and lever mechanism at the cutter-bar. The field capacity is 0.12-0.14 ha/h. The harvesting losses are less than 5%, recoverable which consists of mainly loose stalks. The cost of harvesting crop by this machine is Rs 135.00/ha.*

*1US$ = Indian Rs 14.80.

Acknowledgment: The authors are thankful to Dr. D.S. Rajput, Head, Crop Production Engineering Division, and Director, CIAE Bhopal for their criticism at various stages of the project and also for providing the facilities for this work at the Institute.

Introduction

The harvesting of crops in India is merely done manually using sickles (Saran and Ojha, 1967; Verma, 1970; Devnani, 1980; and Singh, 1981). The harvesting of crops is mechanized at a low level in India. The socio-economic condition of farmers, non-availability of efficient and power source compatible harvesting machines, and technological constraints of some existing harvesters and combines are the main cause for the same. The satisfactory designs of power tiller- and tractor-operated harvesters are available in the country. These machines are few in numbers and form only a part of the harvesting requirement. There is a large gap between manual harvesting and crop harvesting using tractor and combine-run harvesters. The harvesters operated by intermediate power source is of urgent need. There are about 80 million draft animals available in the country. The introduction of power threshers have also spared these draft animals during harvesting and threshing. Most of the time during harvesting season they are kept idle. The annual working hours of these animals could be increased by introducing suitable machines for different operations which are still performed by man.

The development of the industries has caused migration of agricultural labor from villages to cities. Labor wages have gone high many times and touch new high during harvesting seasons. Hence, to make the system efficient and successful, animal-operated harvesters are needed to exploit the potentials of the available draft animals.

Literature Review

The first reaper was developed by Cyrus McCormick as early as in 1933 (Hopper and et al, 1953 and Devnani, 1980). It was patended in the year 1945. This machine was found working satisfactorily for cereal harvesting. The machine had many components such as conventional cutter-bar, reel and crop board. A rake was also used to collect the crop from the crop board manually. A pair of horses were used to pull the machine. There has been approaches for developing a manually operated harvester (Saran and Ojha, 1967) but power for the operation was a great limitation.

The prototypes of McCormick reapers were exported to different countries of the world for evaluation and testing. In India work on such machines was started in

Table 1 Technical Specifications and Test Results of Various Designs of Animal-drawn Reapers

Descriptions	PAU design	IARI design	CIAE design
Type	Animal-drawn	Animal-drawn with 2-3 HP engine	Animal-drawn
Provisions for auxiliary engine	yes	yes	no
Overall length (mm)	2725	—	1850
Overall width (mm)	3725	1800	2100
Overall height (mm)	1225	—	1500
Width of cut (mm)	1065	1125	900
Type of cutter-bar (mm)	Standard 76.2	Standard 76.2	Standard 76.2
No. of strokes/min	9 strokes per 300 mm forward travel	800	680-1200
Machine output (ha/h)	0.15	0.25	0.12-0.14
Draft (kg)	130-180 on plain and on irrigation bounds	—	85-100
No. of persons required	6	—	3
Suitability	wheat, paddy, barley	wheet, paddy, barley	wheet, soybean, bengal-gram, linseed and few other crops

Table 2 Test Results of CIAE Animal-drawn Reaper

Item	Wheat	Linseed
No. of tests	3	3
Crop varieties wheat-	WH-147, Narbada-4	—
Linseed	—	local
Average travel speed (km/h)	2.00	2.25
Effective width of cut (mm)	900	900
Field capacity (ha/h)	0.12	0.14
Field efficiency (%)	66.60	70.00

1961-62 at the Allahabad Agricultural Institute and 1964-65, at Punjab Agricultural University, Ludhiana. Verma (1970), Verma and Bhatnagar (1970) made considerable efforts to develop bullock-drawn reapers suitable for Indian situations. This machine was similar to the McCormick in design but weight was reduced. This design was commercialized. Because of certain limitations such as high draft and more labor requirement while working, this design could not become popular. To resolve the problem of high draft an auxiliary engine was introduced to operate the cutter-bar whereas the machine was pulled by a pair of animals. This design also did not become popular. A brief design information on the PAU reaper is given in **Table 1**.

During 1968, the Indian Agricultural Research Institute (IARI), New Delhi started the research work on animal-drawn reaper. This research effort was similar to the work done at PAU, Ludhiana, excepting the introduction of horizontally operated belt conveyer windrower behind the cutter-bar, Khanna (1970). This additional provision was provided to windrow the harvested crops on one side so that immediate removal and cleaning of swath for the subsequent run of the machine is done. However, the problem of high draft for a pair of bullocks remained unsolved. As per the reports, it is clear that the machine was operated by an auxiliary engine and pulled by a pair of bullocks. Some problem was experienced regarding the goading of the bullocks. Due to its design features, this machine also could not get acceptance of the farmers and manufacturers. The technical information on this machine is also given in **Table 1**.

Singh (1981) carried out some work on design and development of animal-drawn reaper at G.B. Pant Univerity of Agriculture and Technology. He found the relationship between power requirement and plant density at different speeds of operation. The power requirement for the operation of the machine increased with the increase in plant density and speed of operation. It seems that the prototype could not be tested on large scale in the field. The research work on the animal-drawn reaper was further continued by introducing an auxiliary engine in the design Singh and Singh (1987), Bansal and Singh (1988) incorporating a vertical conveyer windrower on the system. The prototype was fabricated and testing is in progress. Simultaneously modifications are on. Similar work was also carried on the design, development and field evaluation of animal-drawn reaper at JNKVV, Jabalpur during the 1970s. In the opinion of the authors, these designs have some limitations such as;

(1) Problem of goading the animals due to noise and vibrations of the auxiliary engine;

(2) The economic feasibility of this machine has to be examined in line of recently developed self-propelled engine-operated, manually guided machines and with other power tiller-operated harvesters even with the limitations of the operating speed of animals; and

(3) High initial cost.

In addition, some efforts on development of oxen-drawn reapers were made in Austria, China and many other countries. The Chinese design is a single-wheel and single-animal machine. This machine has conventional cutter-bar. The design of animal-drawn reaper looks simple and lightweight machine but not enough information is available. This machine has cutter-bar for cutting plants and a reel for gathering the harvested crop on the board.

The overall picture of development of animal-drawn reapers indicates that considerable efforts have been made on the design and development. Due to one or other limitations not even a single design could become popular in any country. Thus seeing the pressing needs of animal-drawn reapers in the country for cereals, pulses and oil seeds, the design and development work was initiated at the Central Institute of Agricultural Engineering (CIAE), Bhopal, Yadav (1984, 1986), Yadav and Yadav (1985, 1987).

Materials and Methods

Design Considerations of CIAE Bullock-drawn Reaper

After conducting a survey and careful study on the various available design on their shortcomings, it was decided to go for a fresh design of a reaper based on the following design criteria;

(1) The machine should be simple, lightweight and sturdy in design;

(2) The draft requirements of the machine should be well within the draftability of a small pair of animals;

(3) It should be functionally flawless for harvesting the crops for which it has been designed;

(4) To meet the requirements of small- and medium-sized land holdings, the unit should be affordable in price;

(5) It should be a multipurpose machine without sacrificing quality;

(6) Harvesting losses by the machine should be within the acceptable limits; and

(7) The machine should be trouble free and easy to operate.

Assumptions

The following assumptions were made in designing the machine and certain information were recorded;

(i) The operating speed of the bullocks is 1.5 km/h (average);
(ii) The speed of the cutter-bar is 0.80 m/s for clean cut and 0.60 m/s for cut;
(iii) Power requirement for cutting and gathering is 0.67 kW/m;
(iv) Available draft from a pair of bullocks is 10% of body weight;
(v) Crops to be delivered in the form of bunches;
(vi) Provisions for power cut-off during operations; and
(vii) Transformation of low force developed from the ground drive traction wheel to high force at the cutter-bar for cutting.

Fig. 1 CIAE bullock-drawn reaper.

Brief Description of Reaper

Fig. 1 shows the CIAE bullock-drawn reaper. The machine is attached on the tool frame at four points. It is also supported on two transport wheels which are adjustable up and down. This arrangement helps in adjusting the height of cut of the crop. The drive to the cutting mechanism is given through an independent front-pushed type spoked traction wheel. Power transmission from the traction wheel is through a set of sprockets and chain drive system. The rotary motion is coverted into a reciprocating action by employing a lever mechanism which helps in improving the low force developed by the traction wheel into high force for cutting (**Fig. 2**). This special feature of the machine reduces the draft requirements considerably. The machine consists of many components such as cutter-bar as-

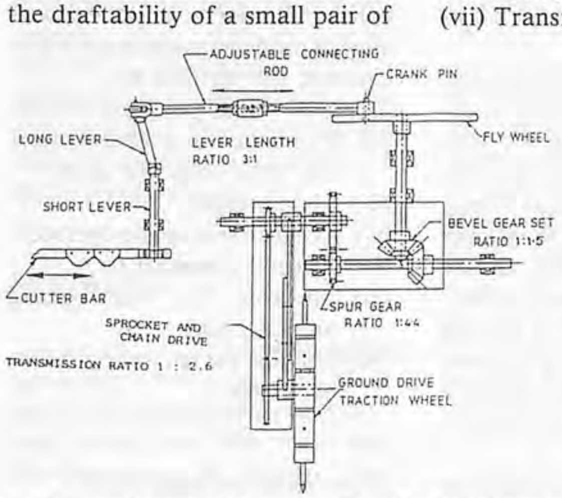

Fig. 2 Power transmission system of CIAE bullock-drawn reaper.

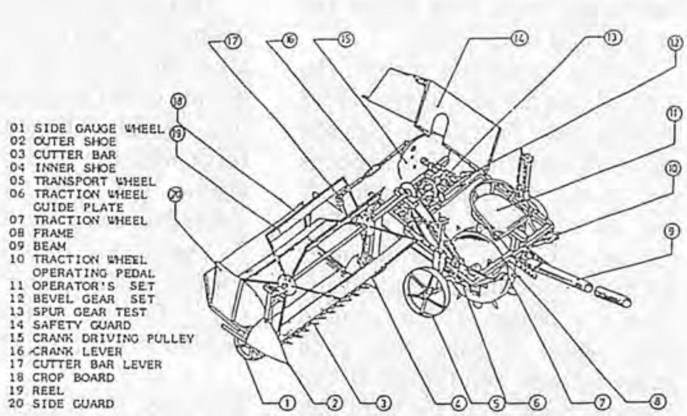

Fig. 3 Various components of CIAE bullock-drawn reaper.

Table 3 Speed of Cutter-bar at Different Operating Speeds of Bullocks

Speed of bullocks (km/h)	No. of strokes (min)
1.5	637
1.6	640
1.7	680
1.8	720
1.9	760
2.0	791
2.1	840
2.2	880
2.3	920
2.4	960
2.5	1000

Table 4 Comparison of Cost of Harvesting

Item	Unit	Cost of harvesting		
		Sickle	CIAE reaper	Tractor-drawn reaper
Initial cost	Rs	20	5000	15000
Salvage value	Rs	2	500	500
Life span	years	3	8	8
Average annual use	h	280	700	700
Effective field capacity	ha/h	0.01	0.01	0.40
Depreciations	Rs/yr	6	562.50	1687.50
Interest @18%	Rs/yr	0.80	450.00	1350.00
Insurance/tax 1% of cost	Rs/yr	—	5.00	15.00
Repair and maintenance 10% of cost	Rs/yr	2	500.00	1500.00
Fuel consumption liter/h	L/h	—	—	4.00
Oil and lubricants	L/h	—	—	0.07
Hiring charges for bullocks	Rs/h	—	50.00	—

Table 5 Cost of Harvesting Wheat by CIAE Reaper in Comparison with other Reapers

Item	Effective field capacity (ha/h)	Average annual use (h)	Power source used	Cost of operation (Rs/ha)+
Sickle	0.01	280	human*	270
Bullock-drown reaper	0.12	700	animal**	135
Tractor-drawn reaper	0.4	700	tractor***	160

* Human labor, daily wage per day has been assumed @Rs. 18.00.
** Pair of bullock with 3 laborers, hiring charges/pair of bullock per day has been assumed @Rs. 50.00.
*** Tractor (above 20 HP) with laborers.
+1 US $ = Indian Rs. 14.80.

sembly, side gauge wheel, crop board, inner shoe and crop board actuating lever. For positioning of the lodged, bent crops and gathering of the cut crop, a fixed bat type reel is provided, including a seat on the frame for comfort of the operator. The details of varius components of the machine are shown in **Fig. 3**. As and when needed, the drive to the cutter-bar and reel is cut-off by lifting the traction wheel with the help of a pedal-operated lever. During transport, the traction wheel is kept hanging with the support of a hook. The crop board is actuated with help of a pedal-operated lever mechanism by pressing and releasing it. The harvested crop is released from the crop board in the form of bunches.

Results and Discussions

The machine was tested for harvesting wheat, linseed, gram and soybean crops. In the case of wheat and linseed, the total crop harvesting losses were below 5% of the total crop yield.

During harvesting season, the top soil gets dry and heavy cracks develop in the field due to high soil moisture depletion. This happens due to the peculiar behavior of soil as shrinkage and swelling characteristics of vertisol under dry moist conditions, respectively. Thus the design of the ground drive wheel is such that even under adverse conditions, it can develop thrust from the hard pan to operate different components of the machine. The pull on the machine was measured using a "NOVATECH" 0-250 kg capacity load cell and indicator unit. The load cell was mounted on the beam with a bracket.

The average value of the following measurement were noted;

(i) Dynamic pull - 107.25 kg
(ii) Average draft - 103.50 kg
(iii) Force required to operate reel (under no load) - 44.30 kg
(iv) Pull without traction drive (ground wheel lifted) - 24.40 kg

This clearly indicates that maximum force was required for operating the cutter-bar unit. A little ground thrust available at the traction wheel is enlarged into a large force with the help of long lever against the hinge point at the cutter-bar using the short lever.

The product of force at ground traction wheel (f) and Larve Lever (L) = Product of Force at Knife Section (F) and small lever (1)

$$f.L = F.1$$

The force (F) is good enough for harvesting the crops.

Conclusions

Many designs of animal-drawn reaper developed in varius places had one or more of the limitations, the major one being the cutting force at the cutter-bar. Economic reasons such as low purchasing capacity of farmers having draft animals as source of power also influences the demand for such machines.

The CIAE animal-drawn reaper has potential to go under commercial production and acceptance amongst the farmers for;

(i) Low initial purchase price;
(ii) Maximum available cutter-bar force with low draft;
(iii) Light weight;
(iv) Comfortable to the operator;
(v) Rugged construction;
(vi) Suitable for small-sized animals; and
(vii) Suitable for harvesting different crops.

(Continued on page 51)

Development of a Variable Geometry Three Point Hitch System

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Abstract

A simple mechanical variable geometry three-point hitch system has been designed and developed is described. The main design objective was to provide a mechanical mode of operation in controlling draft by automatically adjusting the depth of operation when the Variable Geometry System (VGS) attempts to compensate for varying soil resistance encountered.

Initial field experiments have shown that the VGS can work satisfactorily at low range -of forces of up to 10 kN with ploughing depth varying between 14 cm and 17 cm.

The discussion leads to the conclusion that with low-powered tractors, there may be a good rational in introducing the VGS draft control system to replace the conventional hydraulic system and even the more recent innovation of electro-hydraulic system.

Introduction

The basic configuration of the agricultural tractor has undergone steady changes since its introduction more than 100 years ago. Developments in design have enabled the tractor not only to pull an implement, but also to operate an implement attached to the three-point linkage and be able to supply power to drive other machines through the PTO shaft.

Two major improvements have been made with the aim of providing traction. The first is the adoption of the hydraulic three-point linkage, and second is the more widespread use of four-wheel drive, especially in Europe. For example, in 1982 roughly 50% of all tractors sold in Europe were four-wheel drive, whereas in 1977, the figure was around 17% (Rackam et al. 1985).

For the prime mover and the implement to work successfully into a single working unit, the tractor hitch becomes an essential element. In the ASAE standards (ASAE, 1984), the word hitch is defined as a single or combination of articulated points and links through which the tractor delivers tractive effort in the form of pull or push to counteract a draft force of an implement. The three-point hitch system converts an implement into a mounted or integral hitched implement and thus providing an easy implement lift and most profound it allows an automatic control of implement working depth.

The operational aspects of three point hitch systems as free-link or restrained linkage have been reviewed in detail elsewhere (Inns, 1985; Ismail et al. 1983; and Kepner et al. 1980).

Morling (1979), did report another innovation in the mounted hitch systems, that is a mechanical force transfer hitch linkage system. This can be divided into one-point mechanical control hitch (**Fig. 1**) and the three-point mechanical hitch system (**Fig. 2**).

In **Fig. 1**, point F is not fixed to the tractor but it is located on a bellcrank through which a force can be transmitted through another link to a rear bellcrank and then again through another link so as to exert a lifting force in the lift links. X is a pivot added in the hitch beam for flexibility of the tractor and the implement. Point F is movable and as such it is possible to gain load transfer over the conventional design.

The three-point mechanical force hitch system (**Fig. 2**) uses the force in the upper link to develop a lift force in the lift arms through a single bellcrank. The initial line of pull PV for this hitch is through F. However, after force is established in the upper link, the line of pull PV passes through point F' which is the instant centre of the implement relative to the tractor. The main advantage of this hitch is that a low initial line of pull can

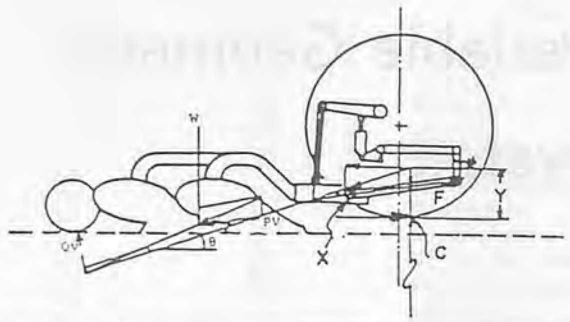

Fig. 1 One-point mechanical hitch linkage.

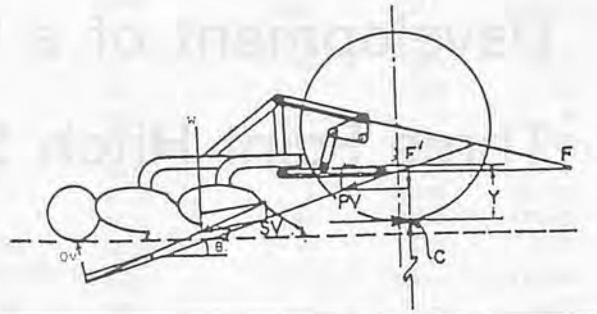

Fig. 2 Three-point mechanical hitch control linkage.

be obtained resulting in a quick entry of the implement into the soil. This is because the point F is farther forward. This hitch is basically a three point variable geometry free link system and the recent developed VGS reported in this paper, was based on the working principles of this mechanical force transfer linkage system.

Design and Development

The connection between the tractor and the drawn or mounted implement is always a challenge to both tractor-hitch and implement designers. As with most other design problems, one best hitch system suitable to operate a variety of implements and operations properly does not exist. It does only for a particular type of implement and for a specific application. This, as Sonne Kofoed et al. (1973) suggested, might be due to the variety of requirements for a hitching device, i.e., drawing, carrying and controlling an implement, which makes it difficult if not impossible, to introduce a distinct coupling arrangement to cover all the needs.

Throughout the design and development stage of the VGS, a number of features that are desirable for a good mounted hitch and functional requirements were considered. These were, among others, as follows:

i) Simplicity, ease of attachment and adjustment;
ii) Stability of the implement when raised and in transport position;
iii) Ability of the system to penetrate hard soil surface; and
iv) A reasonably uniform working depth and a quick entry of the implement to full depth.

Fig. 3 is a schematic illustration of the main parts and principle of operation of the VGS. The lower links are fixed to a hinged bracket (A) and the two lower links are interlinked through a pivot axle (B). The hinged bracket, in turn, is linked with a turnbuckle connector (C) to upper variable link (D) fixed to the upper shaft (E) where the bracket (F) which gives support to the top link is fixed.

Suitable rigid springs (G) to establish the wanted sensibility and characteristic of the system, were fixed to the upper shaft (E) as illustrated in **Figs. 3** and **4**.

The lower pivot axle (B) and the upper shaft (E) were allowed to

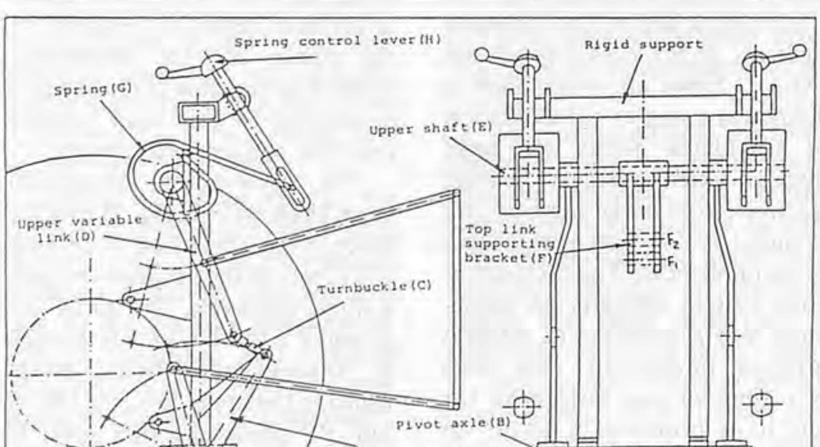

Fig. 3 Main parts of a variable geometry hitch system.

Fig. 4 The developed variable geometric system.

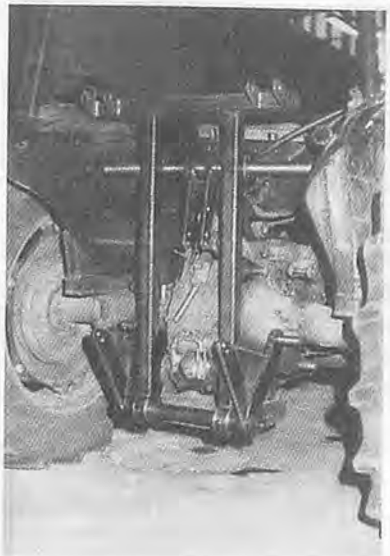

Fig. 5 A rigid support fitted to the tractor.

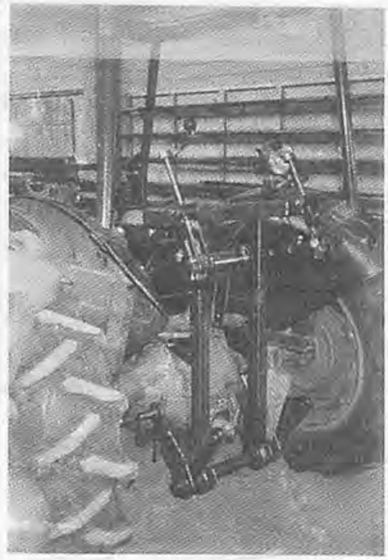

Fig. 6 The variable system fitted to the tractor.

rotate in bearings which were securely housed and fixed to the rigid support. This rigid support for the whole VGS was made by using channel iron and was strongly fitted to the tractor as shown in **Figs. 4, 5** and **6**.

Operational Characteristics and Linkage

The bracket giving support for the top link (F), have alternative linkage attachment point (F1 and F2), so as to give the system a varying sensitivity to the draft control mechanism. It is interesting to note that VGS have been designed such that the movement of a hinged bracket which can be caused by the draft variations, is linked with the bracket giving support for the top link in such a way that parallel movement of the implement is established (**Fig. 7**).

During field operation and when the implement is lowered into the ground, high initial penetration is desirable so as to encourage it to reach its working depth quickly. With the Variable Geometry System, the desirable working depth can be achieved by simply adjusting the spring position (spring tension) by the use of the spring tension adjusting lever (H) as shown in **Fig. 3**.

Due to the linkage geometry of the VGS, low spring tension will make the implement work at shallow depth, whilst if the spring is well tightened, deeper penetration will be achieved.

Fig. 7 is a general layout of the VGS linkage geometry. R is the draft force. If R is increased, say, due to a deep working of the soil engaging implement, the draft line will be higher and steeper due to the movement of the bracket. On the other hand, if the draft decreases, a lower nearly horizontal line of draft will be the result. This means that the operational characteristics of the VGS is identical to the common draft control systems.

Field and Laboratory Evaluation

To assess the operating performance of the VGS, experiments were conducted both in the laboratory and in the field. Laboratory experiments mainly aimed at assessing the control characteristics, while those in the field aimed at assessing the drafting performance of the system.

For all experiments, the control parameter was the spring position which vary the spring tension. Three positions were tested:

I. Tight spring position:
   - Spring tensioned to 70 mm length measured from top of the spring control lever (H).

II. Medium spring position:
   - Spring tensioned to 90 mm.

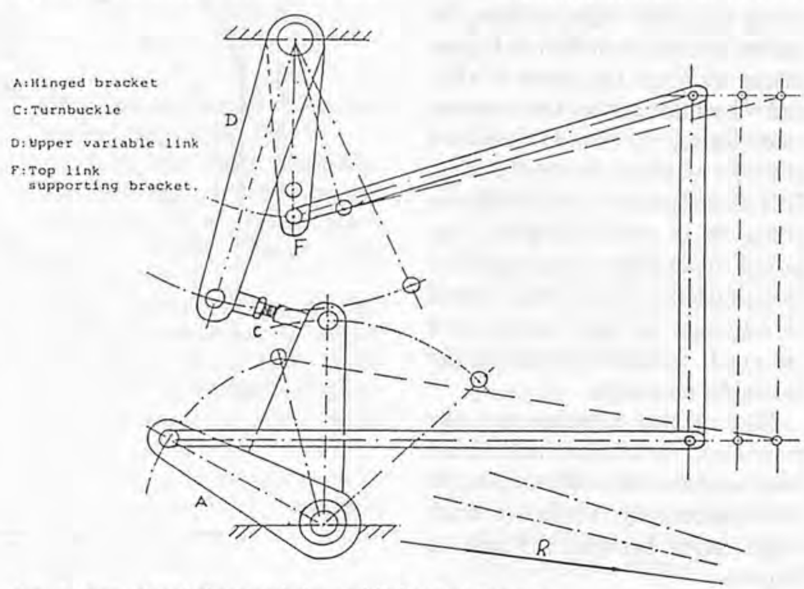

Fig. 7 Operational characteristics and linkage geometry.

III. Loose spring position:
- Spring tensioned to 110 mm.

For each spring position, the maximum drafting force required to cause maximum deflection (δ) on the VGS was measured. A mechanical spring dynamometer was used to record the draft forces (**Fig. 8**). The deflection of the VGS is a measure of the drafting performance and can be used to estimate the anticipated draft force for a particular spring position.

During the field experiments, the MF 135 tractor was hitched to a deepbed cultivator fitted with sweeps. The tractor was operated at constant speed of 1.8 km/h. Field performance of the VGS in achieving the desired quality of work and in maintaining the ploughing depth/draft force at pre-selected spring tension was assessed.

Experimental Results and Observations

Fig. 9 is a graph showing the variation of draft force and deflection for a particular spring position. As expected, when the spring was under tight tension, the system started to deflect at higher values of force (at about 6 kN), and when the spring tension was made loose, the system deflected at very low force (about 0.5 kN). This phenomenon is clearly shown in **Fig. 9**. In practical terms, this would mean that if one wants to plough deeper, the springs should be adjusted to high tension and loosened if shallow depth is the desirable outcome.

During the experiments, the maximum deflection and draft force achieved were 85 mm and 10 kN, respectively, while the draft angle varied between 0.5 and 12 degrees.

The average ploughing depth

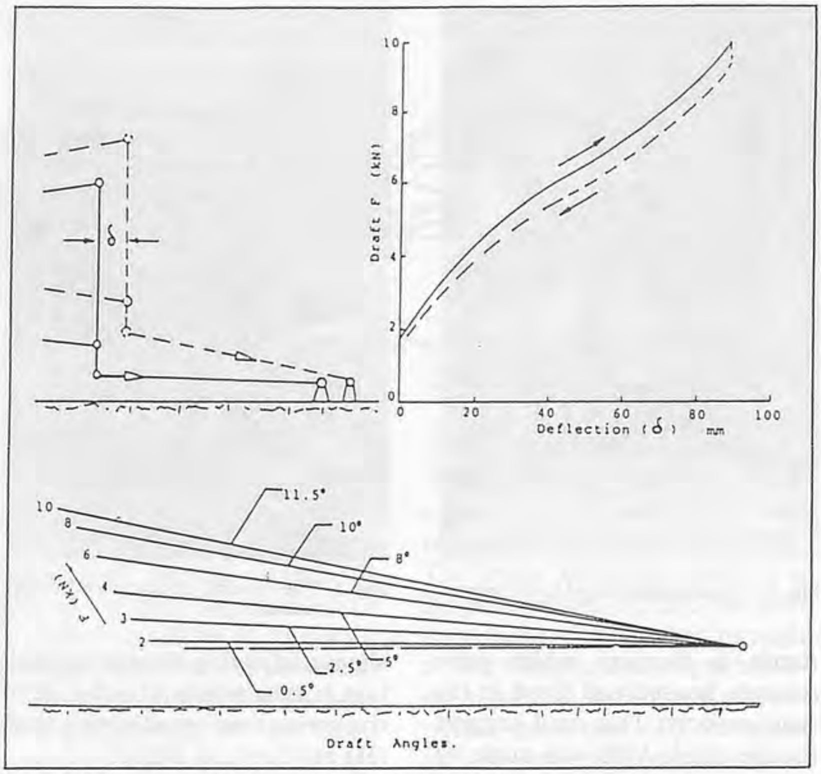

Fig. 8 Characteristics of the variable geometry system.

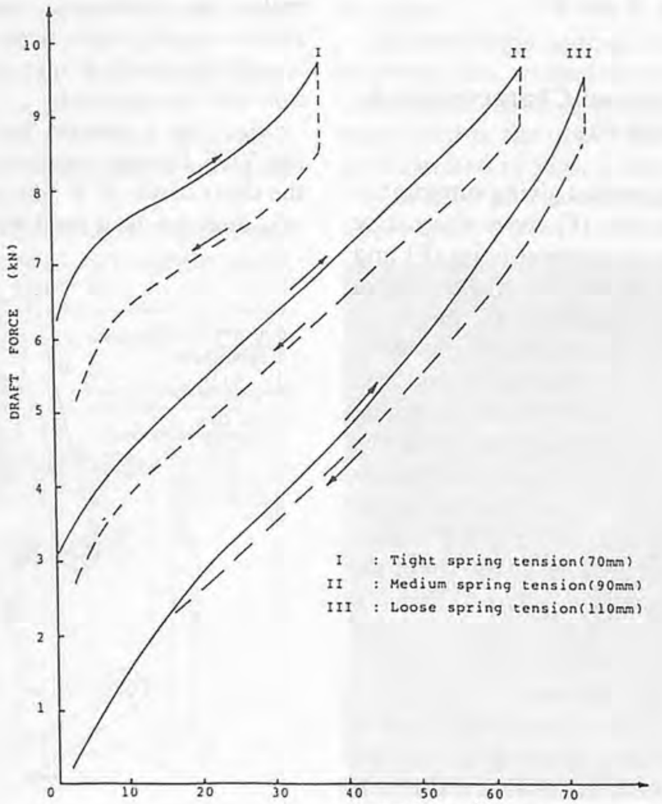

Fig. 9 Draft force and deflection at various levels of spring tension.

when the springs were tensioned to 70 mm, 90 mm and 115 mm was found to be 169 mm, 170 mm and 140 mm, respectively. The values closely agree with the normal range of depth desirable during ploughing operations.

Uniform range of working depth was experienced at each position of the spring tension and the quality of work produced was assessed subjectively to be as good as using the conventional three point hitching system.

Conclusion

Preliminary investigation on the developed VGS reveals that the system can work satisfactorily at low range of draft forces of up to 10 kN. Field trials have also shown that a good quality of work can be achieved with reasonably uniform working depth.

During the field operations, the VGS showed great flexibility by permitting relatively quick entry and attainment of operating depth. Minimum lateral swing was observed, but this can be easily controlled by using side limitters.

Further investigations are required before a firm conclusion could be made. The system should be tested on different soil types using various implements, e.g., mouldboard plough, harrows, planters and sprayers.

With its simplicity and encouraging results produced, this concept of Variable Geometry mechanical hitch system opens up an interesting topic for further improvement and may provide an alternative draft control system for low-powered tractors.

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(Continued from page 46)

Design and Development of CIAE Bullock-drawn Reaper

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Energy Utilization in Chilean Agriculture

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Abstract

The objectives of this research work were to establish the energy requirements and energy efficiency of six important crops in Chile. The information is needed in designing programs of energy saving and to improve its use efficiency in agricultural production.

The experimental work was carried out in South - Central Chile between 1984 and 1988 using wheat, sugarbeet, maize, dry beans, sunflower and potatoes. A total of 233 farmers participated in the project: they were divided into groups representing the most typical production systems for the different crops.

The results showed energy requirements from 1 200-1 600 Mcal/ha for dry beans to 4 890-7 620 Mcal/ha for seed potatoes. The energy efficiency of the crops ranged from 12.6-17.5 for silage maize to 2.2-3.4 for food potatoes. Fuel and fertilizers (N and P) accounted for the largest share (>75%) of all energy expenditures.

Introduction

Energy, being the capacity to do work, is at the heart of all human activities, especially those concerning the production of goods and services. The utilization of energy by man has risen from about 2 000 kcal/day-person one hundred thousand years ago about 300 000 kcal/day-person in the USA in the 1980s (5, 10).

The utilization of energy in agriculture has also risen spectacularly since 1945, explaining in part the large increase in food and fiber production. However, energy consumption has risen faster than food production, causing a reduction in the energy efficiency of most crops. It has been demonstrated (9, 10) that the energy efficiency of maize has dropped form 3.70 in 1945 to 2.47 in 1980.

In Chile, agriculture is very highlly energy-dependent, utilizing large amounts of fertilizers, fuels and biocides. Moreover, about 50% of the energy consumed in the country is imported at a large expense of hard currency. the crops chosen for this study (wheat, sugarbeet, maize, dry beans, sunflower and potatoes) are very important since they cover about 950 000 ha yearly, which represent about 75% of the area planted to annual crops (11).

The major objective of this research project was to establish the energy requirements and the energy efficiency of six important crops. Another objective was to gather information needed to propose actions fostering energy saving and the efficiency of energy utilization in Chilean agriculture.

Materials and Methods

The experimental work was carried out between 1984 and 1988 in South - Central Chile. The crops studied were wheat, sugarbeet, maize, dry beans, sunflower and potatoes.

Typical production systems for each crop were established. All inputs to the production system (man, animal and machinery-journeys, seed, fertilizers, fuels, lubricants, irrigation, biocides) were recorded, from residue elimination and soil preparation to harvesting and storage in the farm or transportation to the processing plant. All these values were transformed into energy units using the equivalents shown in **Table 1**.

The variables studied in each crop and the number of farmers involved are summarized in **Table 2**. Other details for the different crops are as follows:

Wheat — A completely random design in a 2x3x5 factorial arrangement was used; the two categories were irrigation and dryland production; the three

Table 1 Energy Inputs, Equivalences and References

Inputs	Equivalences (kcal)	References
1 man journey	4 352	Pimentel et al (9)
1 animal journey	22 700	Pinto et al (11)
Machinery (1 kg):		
Tractor	22 358	Doering (4)
Plow	15 943	Doering (4)
Harrow	15 273	Doering (4)
Fertililzer	15 330	Doering (4)
Seeder	16 931	Doering (4)
Sprayer	15 000	Doering (4)
Combine	20 930	Doering (4)
Diesel fuel (1 L)	11 414	Cervinka (2)
Gasoline (1 L)	10 109	Cervinka (2)
1 kg of:		
Wheat	3 021	Pimentel (10)
Sugarbeet seed	12 945	Chancellor (3)
Sugarbeet sugar	3 943	Chancellor (3)
Sugarbeet pulp	2 889	Chancellor (3)
Sugarbeet molasses	3 021	Chancellor (3)
Sugarbeet leaves and crowns	2 822	Chancellor (3)
Maize (grain)	3 340	Pimentel (10)
Maize (silage)	3 200	Pimentel (10)
Dry bean	4 000	Pimentel (10)
Sunflower	5 600	Pimentel (10)
Potato	613	Pimentel (10)
Urea (N)	16 485	Lockeretz (7)
Anhydrous ammonia (N)	11 080	Lockeretz (7)
Ammonium nitrate (N)	15 587	Lockeretz (7)
Ammonium sulfate (N)	19 274	Lockeretz (7)
Chilean nitrate (N)	5 037	Hetz y Silva (6)
P	3 380	Lockeretz (7)
Diammonium phosphate (P)	10 543	Lockeretz (7)
K	2 203	Lockeretz (7)
Potassium sulfate (K)	382	Lockeretz (7)
Herbicide (a.i.)	60 816	Pimentel (10)
Insecticide (a.i.)	44 128	Pimentel (10)
Fungicide (a.i.)	23 205	Pimentel (10)

Table 2 Variables Studied in Each Crop

Crop	Variable	No. of Farmers Participating
Wheat	Irrigated/Dryland; 3 ranges seeded area	30
Sugarbeet	Four ranges of yearly seeded area	40
Maize	Grain/Silage; 2 ranges seeded area	58
Dry bean	Two provinces; 3 ranges seeded area	43
Sunflower	Three ranges of yearly seeded area	30
Potato	Seed/Food; 4 geographical locations	32
	Total farmers	233

ranges of yearly seeded area were: <15 ha; 15 to 75 ha; >75 ha; five replications were used for each treatment for a total of 30 farmers. An ANOVA was performed on total and partial energy expenditures, yields and energy efficiency. Also, orthogonal comparisons were made for the interactions zone-size.

Sugarbeet — A completely random design with four treatments (slanted area) and 10 replications, for a total of 40 farmers, were used. The four ranges of yearly planted areas were; <2.0 ha; 2.1 to 4.0 ha; 4.1 to 10.0 ha; >10.0 ha.

Bartlett's, Kruskal-Wallis, and Wilcoxon tests as well as an ANOVA were performed on total and partial energy expenditures, yield and energy efficiency.

Four kinds of outputs at harvest time were considered: a) sugar content; b) sugarbeet pulp; c) molasses, and d) leaves and crowns.

Maize — A completely random design with two treatments (planted area) and replications for a total of 58 farmers were used. The distribution was as follows:

Grain maize:

≤ 10 ha; 25 replications

Grain maize:

> 10 ha; 9 replications

Silage maize:

≤ 10 ha; 15 replications

Silage maize:

> 10 ha; 9 replications

Bartlett's, Wilcoxon-Mann-Whitney's and t test were performed on the results.

Dry bean — A completely random design with three treatments (planted area) in the provinces of Ñuble and Bìo-Bìo were used. A total of 43 farmers participated and they were distributed as follows:

Yearly seeded area	Replication Bìo-Bìo	Ñuble
≤ 3.0 ha	9	10
3.1-10.0 ha	9	5
> 10 0 ha	5	5

Bartlett's and Scheffe's tests as well as ANOVA were performed on the results.

Sunflower — A completely random design with three treatments (planted area) were used. Replications were distributed as follows:

Seeded area	Replications
≤ 10.0 ha	9
10.1-25.0 ha	14
> 25 ha	7

Bartlett's, Newman-Keuls, Kruskal-Wallis, and t tests, as well as an ANOVA were performed on the results.

Potato — The work on potatoes was carried out by Montaldo and Alvarez (8) and their results are included here in order to compare potatoes with the other 5 crops. A completely random design with eight treatments and four replications were used.

The farmers who participated in this research project were chosen at random from lists of producers provided by the Ministry of Agriculture, Bank of the State of Chile, Wheat and Potato Producer Associations, Sugar Industry (IANSA), and the Edible Oil Industry.

The energy efficiency of each crop was expressed as the relation of output energy/input energy; a number like 4 means that for each unit of energy provided to the production system this responds with 4; therefore, the larger the number the higher the efficiency of the crop. Another way to express the energy efficiency was to calculate the amount of energy required to produce 1 kg of produce, i.e., kcal/kg. Therefore, the smaller the number the more efficient the crop.

Results and Discussion

Partial and Total Energy Requirements

Wheat — **Table 3** shows that the total energy requirements for wheat production ranged from 3 044 to 3 912 Mcal/ha. The statistical analysis did not find significant differences between dryland and irrigation production; nor among the ranges of yearly planted area although large farmers tend to use more energy than smaller ones. These values are similar to the ones published by Pinto et al (11) and Pimentel (10).

Examination of partial energy requirements showed that the largest energy expenditures were made as N, fuel-lubricant, seed and P with over 93% of the total. The large energy expenditure in N (about 50%) was caused by the widespread use of urea by wheat producers, because its price is lower than other sources of N.

Sugarbeet — **Table 4** shows that total energy requirements for sugarbeet production ranged from 5 106 to 5 390 Mcal/ha for the smallest and largest yearly planted area, respectively. The statistical analysis did not find significant differences among yearly planted areas, although large farmers used 824 Mcal/ha more than the smallest farmer. Chancellor (3) reported energy requirements for sugarbeet ranging from 6 518 Mcal/ha in Great Britain to 19 437 Mcal/ha in California. The smaller values found in Chile could be explained by the use of Chilean nitrate as a source of N (6), replacement of machinery and irrigation equipment by man and animal energy.

The largest energy expenditures were in fertilizers and fuel-lubricant representing 79.2% of the total. The 3 011 Mcal/ha used as fertilization was recommended by the Sugar Industry (IANSA) and included the following items: P = 1 119; N = 918; K = 276; Gypsum = 692; and Borax = 6, all in Mcal/ha. The use of gypsum and borax solved the problem of sulphur deficiency and the disease called "core rottenness." The statistical analysis of the different inputs showed that the farmers in the smallest range used less fuel - lubricant and more animal journeys than the farmers in the other three groups.

Maize — **Table 5** shows that the total average energy requirements for maize production ranged from 3 577 to 4 052 Mcal/ha for grain maize and from 3 466 to 4 620 Mcal/ha for silage

Table 3 Partial and Total Energy Requirements for Wheat Production in Chile Mcal/ha

Input	Dryland						Irrigated					
	<15 ha		15-75 ha		>75 ha		<15 ha		15-75 ha		>75 ha	
	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%
Nitrogen	1 562	51.3	1 482	43.5	2 057	52.6	1 591	49.1	1 856	49.7	1 577	44.4
Fuel-lubricant	320	10.5	890	26.1	839	21.4	571	17.6	837	22.4	921	25.9
Seed	580	19.0	492	14.4	459	11.7	486	15.0	526	14.1	538	15.2
Phosphorus	380	12.5	336	10.0	415	10.6	290	8.9	332	8.9	331	9.3
Machinery	51	1.7	101	2.9	88	2.3	88	2.7	88	2.4	104	2.9
Biocides	57	1.9	73	2.1	42	1.1	47	1.5	61	1.6	49	1.4
Animal journeys	73	2.4	18	0.5	1	0.0	123	3.8	11	0.3	11	0.3
Man journeys	21	0.7	17	0.5	11	0.3	46	1.4	22	0.6	11	0.3
Total	3 044	100	3 409	100	3 912	100	3 242	100	3 733	100	3 552	100

Table 4 Partial and Total Energy Requirements for Sugarbeet Production in Chile, Mcal/ha

Input	Yearly seeded area (ha)									
	≤2.0 ha		2.1-4.0 ha		4.1-10.0 ha		>10.0 ha		Average	
	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%
Fertilizers (P, N, K, gypsum, borax)	3 011	59.0	3 011	54.5	3 011	55.6	3 011	50.8	3 011	54.8
Fuel-lubricant	815 a[1)]	16.0	1 422 b	25.8	1 224 b	22.6	1 892 b	31.9	1 338	24.4
Man journeys	380	7.4	352	6.4	352	6.5	329	5.5	353	6.4
Seed	259	5.1	249	4.5	243	4.5	229	3.9	245	4.5
Animal journeys	415 a	8.1	201 b	3.6	221 b	4.1	5 b	0.1	211	3.8
Biocides	73	1.4	96	1.7	199	3.6	280	4.7	162	2.9
Transportation	117	2.3	142	2.6	108	2.0	108	1.8	119	2.2
Machinery	36	0.7	50	0.9	59	1.1	76	1.3	55	1.0
Total	5 106	100	5 523	100	5 417	100	5 930	100	5 494	100

1) Different letters indicate significant differences ($p \leq 0.05$).

maize. The statistical analysis did not find significant differences between the yearly planted areas, although, again, the tendency is for the large farmers to use more energy. These values are much smaller than the ones reported by Pimentel (10) for the USA (7 213 to 34 678 Mcal/ha) which included artificial drying with natural gas and electricity. USA values for silage maize (5 355 to 6 254 Mcal/ha) are closer to the requirements found in Chile. Again, the largest energy expenditures were in fuel-lubricant, N and representing about 80% of the total demand.

Dry beans — **Table 6** shows that the total energy requirements for dry bean production ranged from 1 198 Mcal/ha in the province of Bìo-Bìo to 1 610 Mcal/ha in the province of Ñuble. The ANOVA did not find significant differences among the treatment. The tendency to use more energy as the yearly planted area increased is comparable to the findings in wheat, sugarbeet and maize.

Pimentel (10) established energy requirements of 3 132 to 6 966 Mcal/ha for dry bean production in the USA: this larger value is attributed to the use of more N fertilizer and agricultural equipment. The largest energy expenditures were in fuel-lubricant, seed and animal journeys which accounted for 71.3% of the total.

Sunflower — **Table 7** shows that the total energy requirements for sunflower production ranged from 1 471 to 2 456 Mcal/ha. The ANOVA showed significant differences between the smallest yearly planted area and the two other sizes of planted area. This was explained by the utilization of inputs with a smaller energy expenditure (labor and animal traction) by the small farmers (1).

The statistical analysis also showed significant differences in fuel-lubricant utilization between the smallest farmers and the two other groups.

The largest energy expenditures were in fuel-lubricant N and P which accounted for 89.1% of the total.

Potatoes — **Table 8** shows that the total average energy requirements for potato production ranged from 5 276 Mcal/ha in

Table 5 Partial and Total Energy Requirements for Maize Production in Chile, Mcal/ha

Inputs	Grain maize				Silage maize			
	≤10 ha		>10 ja		≤10 ha		>10 ha	
	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%
Fuel-lubricant	1 213	33.9	1 293	31.9	1 296	37.4	1 652	35.8
Nitrogen	1 127	31.5	1 449	35.8	883	25.5	1 434	31.0
Phosphorus	459	12.8	478	11.8	603	17.4	738	16.0
Biocides	259	7.2	327	8.1	158	4.5	284	6.1
Machinery	119	3.3	202	5.0	274	7.9	344	7.4
Man journeys	186	5.2	194	4.7	83	2.4	55	1.2
Animal journeys	128	3.6	25	0.6	83	2.4	26	0.6
Seed	86	2.5	84	2.1	86	2.5	87	1.9
Total	3 577	100	4 052	100	3 466	100	4 620	100

Table 6 Partial and Total Energy Requirements for Dry Bean Production in Chile, Mcal/ha

Inputs	Ñuble Province			Bío-Bío Province			Average	
	≤3.0 ha	3.1-10.0 ha	>10.0 ha	≤3.0 ha	3.1-10.0 ha	>10.0 ha	Mcal/ha	%
Fuel-lubricant	338	547	535	219	485	627	459	32.0
Seed	350	344	328	409	404	368	367	25.6
Animal journeys	305	274	206	288	103	3	197	13.7
Phosphorus	133	236	218	124	220	241	195	13.6
Man journeys	138	131	159	121	102	90	124	8.7
Machinery	48	69	63	25	48	86	57	4.0
Nitrogen	24	0	76	2	28	40	28	2.0
Biocides	5	9	16	10	0	0	6	0.4
Total	1 341	1 610	1 601	1 198	1 390	1 455	1 433	100

Table 7 Partial and Total Energy Requirements for Sunflower Production in Chile, Mcal/ha

Input	Yearly seeded area (ha)							
	≤10.0 ha		10.1-25.0 ha		>25.0 ha		Average	
	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%
Fuel-lubricant	922a[1)]	62.7	1 334b	63.7	1 453b	59.2	1 236	61.6
Nitrogen	132	9.0	312	14.9	510	20.8	318	15.8
Phosphorus	175	11.9	237	11.3	290	11.8	234	11.7
Machinery	51	3.5	83	4.0	79	3.2	71	3.5
Man journeys	59	4.0	58	2.8	66	2.7	61	3.1
Animal journeys	93	6.3	21	1.0	0	0.0	38	1.9
Seed	34	2.3	41	1.9	42	1.7	39	1.9
Biocides	5	0.3	8	0.4	16	0.6	10	0.5
Total	1 471a	100	2 094b	100	2 456b	100	2 007	100

1) Different letters indicate significant differences ($P \leq 0.05$).

Table 8 Partial and Total Energy Requirements for Potato Production in Chile, Mcal/ha[1)]

Inputs	Seed potatoes		Food potatoes		Average	
	Mcal/ha	%	Mcal/ha	%	Mcal/ha	%
Fuel-lubricant	1 752	28.1	1 370	26.0	1 561	27.1
Seed	1 520	24.3	1 482	28.1	1 501	26.1
Nitrogen	1 559	25.0	1 047	19.8	1 303	22.6
Phosphorus	948	15.2	942	17.9	945	16.4
Man journeys	228	3.7	250	4.7	239	4.1
Potassium	191	3.0	137	2.6	164	2.8
Machinery	26	0.3	29	0.5	27	0.5
Animal journeys	15	0.2	19	0.4	17	0.3
Biocides	5	0.1	0	0.0	3	0.1
Total	6 244	100	5 276	100	5 760	100

1) Adapted from Montaldo and Alvarez (8).

food potatoes to 6 244 Mcal/ha in seed potatoes. Seed potato production uses more energy since it is a high technology and well-controlled system.

These values are similar to the ones reported for other countries (8, 10), although variations are found in fuel and labor utilization.

The largest expenditures were in fuel-lubricant, seed, N and P which accounted for 92.2% of the total.

Energy Efficiency of the Crops

Table 9 summarizes the utilization of energy in the six traditional crops studied. The last two columns on the right hand side of **Table 9** show the energy efficiency of each crop.

The last column shows the relation of output/input. By this relation the most efficient crop was silage maize (12.6-17.5) and the least efficient was food potato (2.2-3.4). These values, in general, are much higher than the ones reported for other countries (10), which could be explained by the natural fertility of the soils, the use of natural nitrate as source of N, the high rate of photosynthesis, and the use of gravitational irrigation, more labor and animal traction (1).

The column before the last shows the kcal needed to generate one kg of produce. Sugarbeet and potatoes needed little amounts of energy to generate one kg of produce. On the other hand, dryland wheat, sunflower and dry beans needed larger quantities of energy to generate one kg of produce.

Table 9 Summary of Energy Utilization in Traditional Crops in Chile

Crops	Total requirements Mcal/ha	Three largest expenditures and % of the total		Energy efficiency	
				Kcal/kg	Output/Input
Maize (silage)	3 470-4 620	F - N - P;	81.6	245- 348	12.6-17.5
Maize (grain)	3 580-4 050	N - F - P;	78.8	490- 531	8.3- 8.4
Sugarbeet	5 100-5 930	F - P - N;	61.5	109- 135	6.9- 8.8
Sunflower	1 470-2 460	F - N - P;	89.1	913-1 168	4.9- 6.3
Dry bean	1 200-1 610	F - S - AJ;	71.3	723-1 002	3.3- 5.9
Wheat (irrigated)	3 240-3 730	N - F - S;	84.5	655- 819	3.7- 4.8
Wheat (dryland)	3 040-3 910	N - F - S;	83.5	1 081-1 119	2.7- 2.8
Potato (seed)	4 890-7 620	F - N - S;	77.4	160- 255	2.4- 3.9
Potato (food)	4 050-5 780	S - F - N;	73.9	193- 282	2.2- 3.4

Nomenclature: N = nitrogen; F = fuel; S = seed; P = phosphorus; AJ = animal journeys.

Conclusions

1. Total energy requirements for the production of crops ranged from as low as 1 200-1 600 Mcal/ha for dry bean to as high as 4 890-7 620 Mcal/ha for potatoes (seed);

2. In most crops, fuel and fertilizers N and P accounted for the largest share (>75%) of all energy expenditures. The seeds represented some importance for potatoes and dry beans in N and P use.

3. The energy efficiency of the crops, as measured by the relation output/input, ranged from 12.6-17.5 in maize (silage) to 2.2-3.4 in potatoes (food). On the other hand, only 109 to 135 kcal are required to produce one kg of sugarbeet, and 1 081 to 1 119 kcal are required to produce one kg of wheat in dryland production;

4. Less energy, hence more efficiency, is being used in Chilean agriculture as compared to the USA, United Kingdom, Germany and France.

5. Energy savings could be accomplished by the use of animal traction, to save fuel, whenever the operation, area and timeliness allow it, and by fertilizing according to the needs of the soils. Energy efficiency could be improved by timely application of good agronomic practices to increase yields.

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Energy Input vs Crop Yield Relationship for Four Major Crops of Northern India

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Abstract

Data regarding energy inputs and crop yields connected to 500 crop plots representing the holdings of 24 farmers of six villages of Meerut district of Northern India region, collected during a previously conducted year-long survey were analyzed statistically to establish mathematical relationships between energy inputs and crop yields of wheat, sugarcane and maize.

For all the three crops, yield seemed to be linearly correlated with total energy input. Wheat yield showed highly significant linear relationship with the total energy input applied before the crop matures (field operations energy and fertilizer energy) while sugarcane yield was found related to field operations energy input only.

Fertilizer energy input was found to affect wheat and maize yield more than irrigation energy while irrigation energy input was most influencing on sugarcane. In general, crop yields did not show any direct relation with tillage energy.

Introduction

In agriculture sector planning, the conflicting demands i.e. maximization of food production from limited arable land and minimization of energy inputs require the formulation of policies which are based on a thorough understanding of the interaction between crop yields and energy inputs in the form of tillage energy, irrigation energy, fertilizer energy, etc.

In most of the energy analysis procedures crop production is viewed as a "black-box" and energy computations are made on aggregate basis. Even when they are disaggregated according to source, the attention still continues to be on the total consumption by "black-box". This lumping of energy calculations is good enough for regional energy databases and inter-regional comparisons, but rarely adequate for making any sensible recommendation because it does not permit an easy identification of particular stages in agricultural production that require the attention of planners and decision makers in the government and the farmers engaged in the production process.

This paper presents a study carried out to establish and analyze the relationship between energy inputs and crop yield.

Review of Literature

During late sixties, Giles (1975) developed his famous relationship between the available horsepower per cultivated hectare and average crop yield after studying some 23 regions, countries, districts and farms, covering a time span of about six years. He reported his finding through a visual representation shown in **Fig. 1** which dominated the thinking of agricultural engineers and scientists for a long time. Later it was realized that this correlation overlooks the effect of other major inputs like fertilizer, seed, pesticide, etc.

Fluck and Baird (1980) hypothesized from available data that the response curve of yield to level of mechanization energy input is shaped as shown in **Fig. 2** which indicates that the highest partial energy productivity is achieved at the point of minimum mechanization energy inputs and increasing mechanization energy increases crop yield at a decreasing rate. Somewhat similar hypothetical yield responses were reported by them for irrigation and fertilizer energy input.

Singh and Chancellor (1975) presented a detailed study of energy inputs in different farm categories, namely bullock-farms, tubewell-farms, and tractor-farms

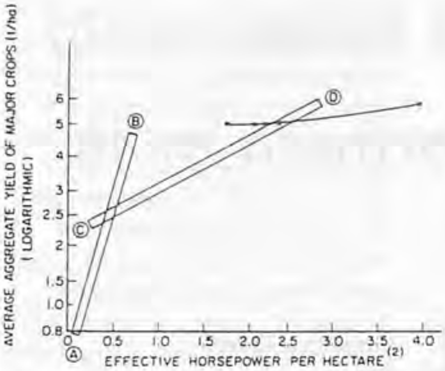

Fig. 1 Relationship between yield and power available.

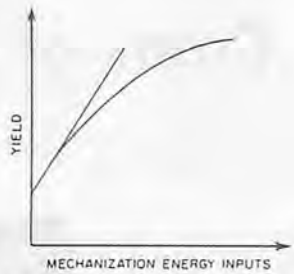

Fig. 2 Yield vs mechanization energy input.

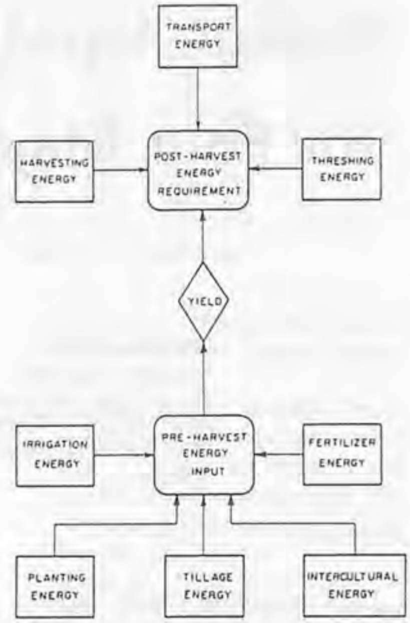

Fig. 3 Classification of energy inputs and their interrelation with crop yield.

of Meerut district of Northern India. They concluded that there was little evidence to show that crop yields could be affected by the type of power source used by the farmers and that increase in yield was the integrated effect of all the inputs. However, the availability of mechanical power for high rates of application during specific periods permitted farmers to use different production strategies thus resulting into increased annual production of food and commercial crops.

Stout (1980) assembled data from FAO statistics and showed that in developed countries the average crop yield was 2631 kg/ha with 19.4 GJ/ha of energy input and in developing countries yield averaged 1328 kg/ha with one-tenth as much commercial energy input.

Makhijani and Poole (1975) analyzed the data on energy requirements of agriculture for India, China, Taiwan, Japan and USA and found that as the use of irrigation and fertilizer increases the production per hectare increases and that the total energy requirement per ton of the crop decreases rapidly.

Methodology

Daily direct and indirect energy inputs into various crop production activities on 500 crop plots of 24 farmers of six villages of Meerut district of Northern India region and respective crop yield of these plots were entered on a database program for organization, classification and preliminary analysis of data (Singh, 1978). Energy inputs were classified according to cultural operations and their functional relation was conceptualized as shown in **Fig. 3**. Preharvest energy input was defined as the one applied before the crop matures. It was further divided into field operations energy (direct energy) consisting of tillage energy, planting or sowing energy, irrigation energy and intercultural operations energy inputs and fertilizer energy (indirect energy). While the field operations energy was the direct energy consumed in farm operations, the fertilizer energy was the energy consumed indirectly in manufacturing, storage, distribution of fertilizers and related activities. The post-harvest energy inputs included energy used for harvesting, threshing and transporting of matured crop, so the amount of these inputs was directly propotional to the quantity of crop handled. The crop yield was assumed to be dependent on the inputs applied before the crop is harvested.

All the energy inputs were computed using recorded power ratings of bullocks, electric motors, tractors, and time consumed by different operations. Human laborer was rated at 0.07 kW (0.1 hp) which is widely used in energy analysis procedures. All the fertilizers were first converted into their nitrogen contents and then fertilizer energy input was calculated by using the equivalent energy value of nitrogen as 15180 kcal/kg as recommended by Pimentel (1980).

Computations of energy inputs and crop yield were done on per-hectare-basis for each individual plot. The use of pesticides and other material inputs on studied plots was negligible and since they represented narly similar geographical locations, the effect of uncontrollable inputs like weather and soil type was assumed to be same on all plots.

The farmers were grouped into five categories according to direct energy sources available to them as suggested by Singh and Chancellor (1974). They represented five well defined increasing mechanization levels as given below.

Category I: Farmers with most or all of their land unirrigated and having animate energy sources only for farm operations.

Category II: Farmers with most or all of their land irrigated by persian wheel or canal and having animate energy sources only.

Category III: Farmers using electric motors for irrigation purpose only and having animate energy sources for all other operations.

Category IV: Famers using electric motor for irrigation and to run stationary machines like wheat thresher, cane crusher and corn sheller etc.

Category V: Farmers owning a tractor mainly for tillage and transportation and using electric motor to run stationary machines and irrigation pump.

Ninety six plots of HYV wheat representing the holdings of 20 farmers, 95 sugarcane plots of 21 farmers and 40 maize plots were selected for subsequent analysis.

Since the data had been collected from farmers' fields with the aid of suitable interview proforma, interview being conducted with each farmer once in every two weeks; a wide variation in yield and energy inputs per hectare was anticipated. To overcome this problem and to verify the results at different stages a 3-level analysis was used. Thus for establishing energy input-crop yield relationships three sets of data, namely, category-wise, farmer-wise and plot-wise were obtained.

Statistical regression with various natures of curve were tried on each data set. Category-wise analysis was useful to identify initially the nature of relationship between energy input and crop yield and then the trends were reinforced through farmer-wise and plot-wise regression. Maize crop with a sample size of 40 plots only did not permit such classification of data, therefore, only plot-wise analysis was carried out for it. It was assumed that the crop yield response to pre-harvest energy input was the resultant of yield responses to individual components of pre-harvest energy and field operations energy. From various types of regression equation tried on each data set only statistically significant results are discussed below.

Results and Discussion

Wheat Yield vs Energy Inputs

Wheat is one of the major crops of the Northern India region and the country too. **Table 1** shows the average enrgy inputs and wheat yield on per-hectare-basis for the farmers of different categories, it shows that farmers of category IV applied the maximum pre-harvest energy input (2366 kWh/ha) and obtained maximum yield (3.6 t/ha). The farmers of caegory I applied minimum pre-harvest energy input (427 kW/ha) and had minimum yield (1.68 t/ha). Regression curve shown in **Fig. 4a** for category-wise analysis is a straight line with R^2 value of 0.87 and F-value of 26 (significant at 5% level). The following equation represents this straight line relationship.

$$Yw = 1207 + 0.94\ (Xw) \qquad (1)$$

where

Yw = Wheat Yield (kg/ha)

Xw = Pre-harvest Energy Input (kWh/ha)

Farmer-wise analysis confirm this straight line relationship (**Fig. 4b**) and it gave following regression equation with $R^2 = 0.64$ and $F = 30$ (significant at 5% level) for a set of 20 farmers.

$$Yw = 1302 + 0.98\ (Xw) \qquad (2)$$

Plot-wise analysis further establishes this linear response of wheat yield to pre-harvest enrgy input. It should be noted here that the number of wheat plots under analysis was 95. The curve is hown in **Fig. 4c** and the equation obtained for this curve with $R^2 = 0.48$ and $F = 86$ (significant at 1% level) is as follows.

$$Yw = 1636 + 0.84\ (Xw) \qquad (3)$$

The farmers of category V owned maximum power sources and therefore applied maximum field operations energy input (927 kWh/ha) followed by the farmers of category III (726 kWh/ha). Both groups had comparable yields of 3.1 t/ha and 3.17 t/ha, respectively. The farmers of category IV applied lower field

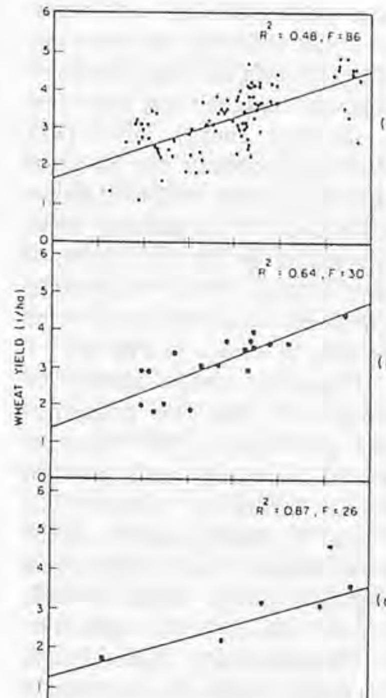

Fig. 4 Wheat yield vs pre-harvest energy input (a) Category-wise analysis, (b) Farmer-wise analysis, (c) Plot-wise analysis.

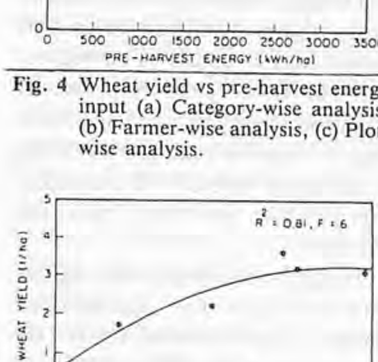

Fig. 5 Effect of field operations energy input on wheat yield.

operations energy input (682 kWh/ha) than the farmers of category V and III, but had maximum yield. Farmers of category I and II, owning only animate sources used very low field operations energy, their yield were also low (1.68 t/ha and 2.2 t/ha, respectively). The regression curve of wheat yield to field operations energy input indicated a stabilization of yield after about 800 kWh/ha of field operations energy input as shown in **Fig. 5**.

The farmers of category IV used maximum fertilizer energy input (1684 kWh/ha) with maximum yield followed by farmers of category V and III. The farmers of category I applied very low level of fertilizer energy input (233 kWh/ha) probably due to poor economic status and irrigation limitations. The regression curve for yield to fertilizer energy input were straight lines indicating strong coorrelation in all the three analyses as shown in **Fig. 6**.

Irrigation energy inputs of farmers of first two categories were quite low as they relied on rainfall, canals and persian wheels. Farmers of category III, IV and V, having electric motor driven pumps, used comparable irrigation energy inputs of 502, 506 and 583 kWh/ha, respectively. Comparatively higher irrigation energy inputs allowed them to apply higher fertilizer doses and obtain higher yields. The regression curves of yield response to irrigation energy input as shown in **Fig. 7** indicates that 550 kWh/ha is sufficient amount of irrigation energy for existing cultural practices.

Tillage energy input was highest (341 kWh/ha) for farmers of category V as they used tractor tillage system while others used bullocks. The farmers of category IV applied quite low tillage energy input (175 kWh/ha) but still got maximum yield. The farmers of

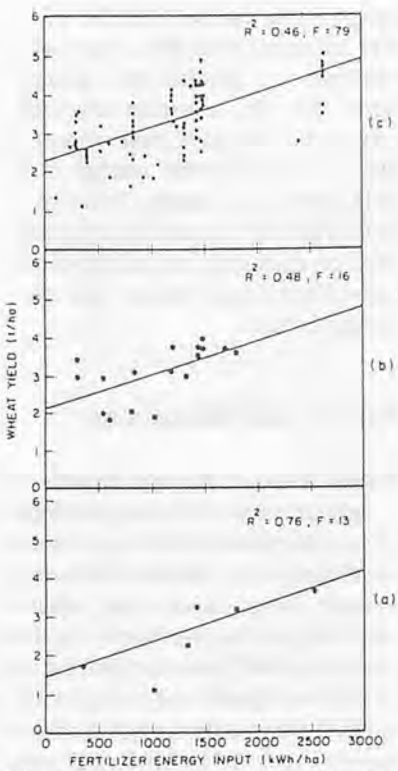

Fig. 6 Effect of fertilizer energy input on wheat yield (a) Category-wise analysis, (b) Farmer-wise analysis ,(c) Plot-wise analysis.

category II with 239 kWh/ha and category III with 220 kWh/ha did not have much difference in their tillage energy inputs, but there was a considerable difference in their yields as evident from **Table 1**. The regression procedure also did not provide any significant correlation between tillage energy inpout and wheat yield.

In a nutshell, the analysis on wheat data gave significant indications that wheat yield was linearly

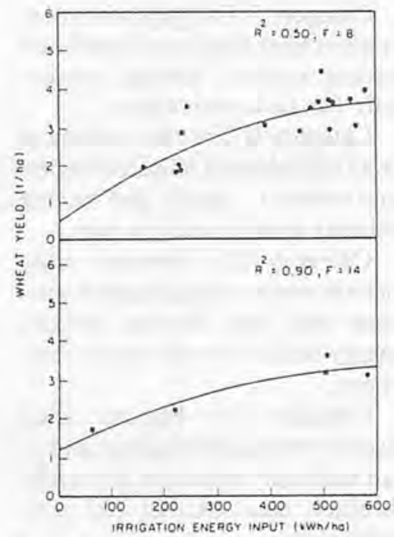

Fig. 7 Effect of irrigation energy input on wheat yield, (a) Category-wise analysis, (b) Farmer-wise analysis.

correlated with pre-harvest energy input. Among the components of pre-harvest energy, fertilizer energy (indirect energy) showed more direct effect (straight line) on yield than field operations energy input (direct energy) which showed a stabilization of yield after 800 kWh/ha. Further 500 kWh/ha of irrigation energy input seemd sufficient in current cultural practices while seemingly tillage energy input did not affect wheat yield.

Sugarcane Yield vs Energy Inputs

Sugarcane is the most important commercial crop of the region as the farmers grow it to sell to sugarmills in the region. **Table 1** shows the average energy inputs

Table 1 Energy Inputs and Yield of Wheat and Sugarcane for Farmers of Different Categories

Crop	Cat.	Tillage energy (kWh/ha)	Irrigation energy (kWh/ha)	Field operation energy (kWh/ha)	Fertilizer energy (kWh/ha)	Pre-harvest energy (kWh/ha)	Yield (t/ha)
Wheat	1	120	64	191	233	423	1.68
	2	239	220	469	888	1357	2.20
	3	220	502	726	944	1670	3.17
	4	175	506	682	1684	2366	3.60
	5	341	583	927	1199	2126	3.10
Sugarcane	1	31	383	423	0	423	38.82
	2	61	424	513	157	670	35.21
	3	72	905	1012	1157	2169	46.38
	4	36	752	798	1388	2186	41.42
	5	103	887	1022	1005	2027	47.37

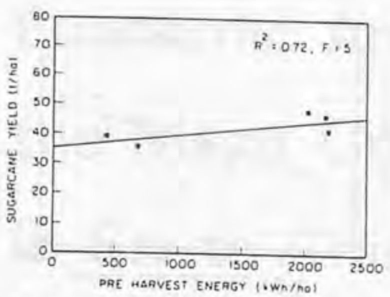

Fig. 8 Sugarcane yield vs pre-harvest energy input (Category-wise analysis).

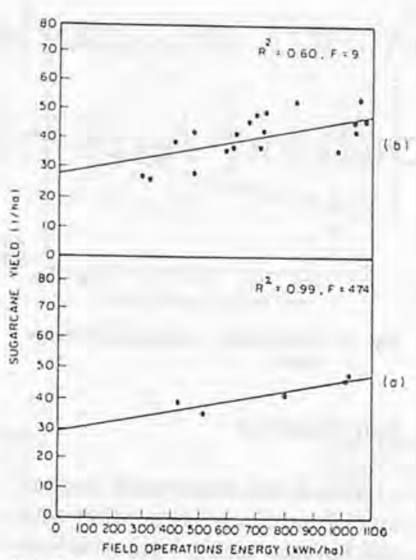

Fig. 9 Sugarcane yield vs field operations energy (a) Category-wise analysis, (b) Farmer-wise analysis.

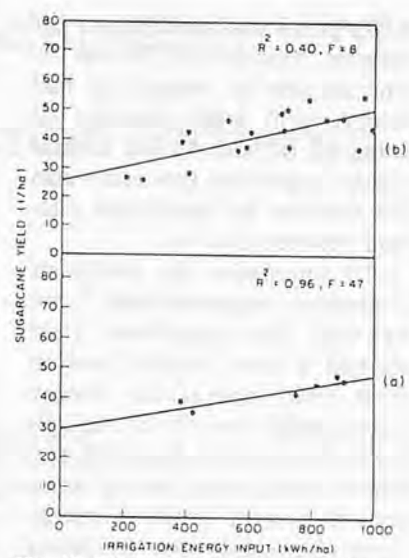

Fig. 10 Effect of irrigation energy input on sugarcane yield (a) Category-wise analysis, (b) Farmer-wise analysis.

and sugarcane yield for farmers of various categories. The farmers of category IV used maximum pre-harvest energy input (2186 kWh/ha) but their yield (41.42 t/ha) was substantially lower than that of farmers of both category III 46.38 t/ha and category V (47.37 t/ha) with 2168 kWh/ha and 2027 kWh/ha, respectively. The farmers of category I and II had much lower pre-harvest energy inputs and their sugarcane yields were also low. Sugarcane yield showed a moderately significant linear response with pre-harvest energy input in category-wise analysis as shown in **Fig. 8**. Following regression equation with $R^2 = 0.72$ and $F = 5$ (significant at 5% level) was obtained.

$$Ys = 31.22 + 0.0064\ (Xs) \quad (4)$$

where,

Ys = Sugarcane Yield (t/ha)

Xs = Pre-harvest Energy Input (kWh/ha)

Farmer and plot-wise analysis for pre-harvest energy did not give any significant result.

Field operations energy input was highest for farmers of category V (1022 kWh/ha) who got maximum yield (47.37 t/ha) followd by farmers of category III with 1012 kWh/ha who obtained next highest yield of 46.38 t/ha. The farmers of category IV applied much lower field opertions energy input (798 kWh/ha) than farmers of above two categories and their yield was also lower (41.42 t/ha). The farmers of category I and II applied still lower field operations energy and had lower yields. Sugarcane yield was regressed on field operations energy and it was found that it responded more significantly to field operations energy than to pre-harvest energy which included a major contribution of fertilizer energy input. A simple comparison of **Fig. 9** which shows the yield response to field operations energy along with statistical significance with the **Fig. 8** and its statistical significance proves this point. The linear regression of sugarcane yield on field operations energy gave highly significant results in both category and farmer-wise analyses. The following equations were obtained by this procedure:

Category-wise analysis:

$$Ys = 23.13 + 0.023\ (Xsf) \quad (5)$$

Farmer-wise analysis:

$$Ys = 28.36 + 0.17\ (Xsf) \quad (6)$$

where,

Xsf = Field Operations Energy Input (kWh/ha)

The Eq. (5) has $R^2 = 0.99$ and $F = 474$ (significant at 1% level) and Eq. (6) has $R^2 = 0.40$ and $F = 8$ (significant at 5% level).

The irrigation energy inputs of farmers of category III (905 kWh/ha) and category V (887 kWh/ha) were not much different and so were their yields. The irrigation energy input of 752 kWh/ha and sugarcane yield of 41.42 t/ha of farmers of category IV were lower than farmers of above two categories. The farmers of category I and II had very low irrigation energy inputs and their yields were also low. Regression curves of yield on irrigation energy input are shown in **Fig. 10** and they are linear indicating a strong influence of irrigation energy on sugarcane yield.

Again **Table 1** shows an irregular pattern of fertilizer energy input with decreasing order of sugarcane yield. Heavy contribution of fertilizer energy input in pre-harvest energy except for farmers of category I who did not apply any fertilizer makes it responsible for poor correlation between pre-harvest energy and sugarcane yield.

Tillage energy input of farmers of category IV was very low (36 kWh/ha), only slightly higher than farmers of category I (31 kWh/ha). It was much higher for farmers of category II, III and IV. The farmers of category II had lowest yield while farmers of category III and V had highest yields. Regression procedure also did not give any significant relation between the two.

To summarize the results of analysis on sugarcane data, it can be said that sugarcane yield showed a more reliable relation with field operations energy having major contribution of irrigation energy input than with pre-harvest energy input having major contribution of fertilizer energy input. Separately also irrigation energy affected sugarcane yield more driectly than any other energy input taken individually.

Maize Yield vs Energy Inputs

As mentioned earlier, because of small sample size of 40 plots, only plot-wise analysis was carried out for maize. The analysis revealed a significant linear relation of maize yield with pre-harvest energy input as shown in **Fig. 11** and following equation with $R^2 = 0.52$ and $F = 41$ (significant at 1% level) was obtained.

$$Ym = 878 + 0.98\ (Xm) \qquad (7)$$

where,

Ym = Maize Yield (kg/ha)

Xm = Pre-harvest Energy Input (kWh/ha)

It was found by regression that comparatively fertilizer energy input showed a better correlation with maize yield (**Fig. 12**) than irrigation energy and tillage energy inputs.

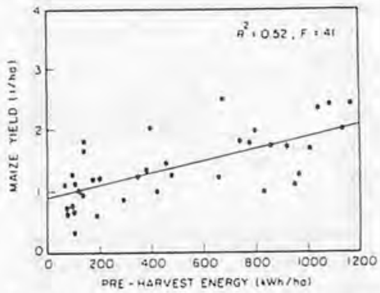

Fig. 11 Maize yield vs pre-harvest energy input.

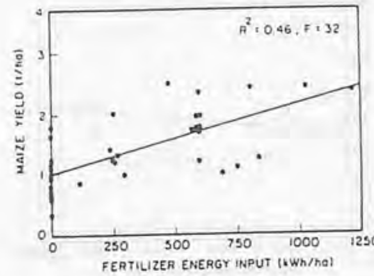

Fig. 12 Effect of fertilizer energy input on maize yield.

Conclusions

Wheat and maize yields showed significant linear correlation with pre-harvest energy input which includes field operations energy and fertilizer energy inputs while sugarcane yield was closely related to the field operations energy input.

Fertilizer energy input showed a more direct effect on wheat and maize yields while irrigation seemed to influence sugarcane yield more prominently.

In general tillage energy input was not found to affect crop yields significantly.

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Economic Analysis on the Adaptability of the Major Grain Post-production Patterns in South China

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Abstract

An analysis model was established in order to evaluate the adaptability of grain post-production patterns from harvesting to drying for different economic circumstances using three components, i.e., labor cost saving effects, benefits from increased production or reduced losses, and income from saved labor. The system analysis on four major patterns of grain post-production existing in South China was undertaken using the model. The results indicate that in all operation areas of 10 ha/year, the pattern: "manual harvesting-manual threshing-manual cleaning-sun drying" was suitable for the areas where tthe technical and economic conditions were relatively lower and the manpower was abundant with the average value of labor being less than 2.62 yuan/day; the patterns: "manual harvesting-mechancal threshing-mechanical cleaning-sun drying" and "mechanical harvesting-mechanical threshing-mechanical cleaning-sun drying" were fit into the areas where the technical and economic conditions were moderate with the average value of labor being from 2.62 to 3.57 yuan/day and from 3.57 to 10.30 yuan/day, respectively: the pattern: "combine harvesting and threshing-mechanical cleaning-sun drying" was adaptable for the areas where the technical and economic conditions were better and short of manpower with the average value of labor being 10.30 yuan/day. The study suggests that these conditions could be applied to help the farmers make the best choice and improve the grain post-production system.

*The study is a part of the project "Grain Post-harvest System Analysis in China" funded by IDRC. Ottawa, Canada.

Introduction

The grain post-production patterns include such processes as harvesting, threshing, transporting, drying and storage. The alternative combinations of processes adopting different techniques and equipment consist of different patterns. In South China, there were many patterns which were formed and developed relating to historical and natural causes. But they were mostly decided by the social and economic conditions. The present report tries to analyze the quantitative relations between the four major grain post-production patterns and different economic conditions so as to help prospective adoptors or users to make the best choice.

Background

At present , all means of operations, including manual, animal and semi-mechanical co-exist in the grain post-production system in China. Whether machines can replace man and animal would not only be determined by the technological feasibility but also by the economic effects. The precondition for technological feasibility is the economic effects. Therefore, the technological feasibility and economic effects which could be reflected by the economic benefits, should be evaluated. In any case, the adoption of the feasible technologies lies in economic effectiveness which can be quantitatively measured by using three components, i.e., labor cost-saving effects (s1), benefits from increasing production and reducing the losses (s2), and the interest from saved labor (s3).

Analysis Model

Labor Cost Saving Effects (s1)

The economic benefit from using machines is that the expense for the input to mechanical operations should be lower than that by manual and animal power, i.e., under conditions of certian income, the interest saved in the mechanical operations as compared with the operations by manual and animal power can be expressed in the following equation:

$$S1 = (a1 - a2)LW + (b1 - b2)W - (c1 - c2) \quad (1)$$

where,

S1 = labor cost saved from using machines (yuan).

L = the average value of manual labor (yuan/day).

W = areas operated in a year (ha/year).

a1, a2 = working days/ha by manual and animal powers and mechanical power, respectively.

b1, b2 = variable costs of operation by manual and animal power and that by mechanical power, respectively, (yuan/ha) (see table 3).

c1, c2 = annual depreciation of mechanical equipment and farm tools operated manually and by animal power, respectively, (yuan/year).

If $S1 > 0$, it is favoured; $S1 < 0$, unfavoured; $S1 = 0$, the balance of cost-benefit.

Benefits from Increased Production or Reduced Losses (S2)

The conditions for agricultural production can be improved if the farming operations are mechanized. Mechanization plays an important role in timely operations of farm work and securing the productivity of the crops under unfavourable weather conditions. Increasing productivity and reducing losses can be shown in the following equation.

$$S2 = (R1 - R2)I \quad (2)$$

or

$$S2 = (P1 - P2)I \quad (3)$$

where,

I = grain price per kg.

R1, R2 = yield per unit areas with operations of manual-animal power and mechanical power, respectively.

P1, P2 = losses per unit area of grain as operated by manual-animal power and mechanical power, respectively.

Benefits from Saved Labor

The transfer to other occupations after the replacement of mechanical power (S3) can be expressed by the following equation:

$$S3 = S31 + S32 + S33 + S34 + S35 + S36 \quad (4)$$

where,

S31, S32, S33, S34, S35, S36 = Benefits from labor saved which was transfered to other occupations instead of farming.

The variable, S3, shows the value created by labor transfer from grain post-production to other occupations after using the mechanical power. If there was available work for the transfered labor, the income would be increased. As the benefit from the labor transfer was significant, $S3 > 0$; otherwise, $S3 < 0$, meaning that after the mechanizations of all the operations in grain post-production, although the labour was saved there was no occupation available for the transfered labor. Therefore in this case the variable, S3, was negative.

Based on the analysis above, whether the actions for the adoption of any advanced technologies in grain post-production should be taken or not must be based on the evaluations with the three components, S1, S2, S3, so that the possibility of the new technologies in given location could be determined. Following is the economic analysis of grain post-production with four major post-production patterns in South China.

Applications of Analysis Model

Based on the levels of mechanization in grain post-productions, the major patterns existing in South China are summarized in **Table 1**. System analysis on these patterns is undertaken as follows:

Analysis of Cost-saving Effects (s1)

Operation costs and labor allocation in these four patterns were analyzed with the data collected from Ningbo, Jinghua and Jiaxing

Table 1 Four Major Grain Post-production Patterns in South China

Pattern	Harvesting	Threshing	Cleaning	Drying
I	sickle	hand threshing	wooden winnower	sunlight
II	sickle	pedal thresher	electric blower	sunlight
III	mechanical reaper	motor thresher	mechanical vibrating screen combined with an electric blower	sunlight
IV	combine-harvester		mechanical vibrating screen combined with an electric blower	sunlight

Table 2 Labor Allocation in Four Major Grain Post-production Patterns (Unit: labor/day)

Item	Pattern I	II	III	IV
Harvesting	4	8	1	1
Harvesting and gathering	0	0	3	2
Threshing	4	4	6	0
Transporting	2.5	5	5	4
Cleaning	1	2	2	1
Total	11.5	19	17	8

Table 3 Variables of Four Major Grain Post-production Patterns

Item	Pattern I	II	III	IV
Productivity (ha/day)	0.33	0.67	0.93	1.07
Labor expense (day/ha)	34.33	28.36	18.28	7.48
Price of machines (yuan)	563.6	657.8	2 457.8	15 091
Depreciation (yuan/year)	63.4	74.0	276.5	1 697.8
Variable costs (yuan/ha)	1.5	16.1	37.5	114.6
Cost of power	0.0	11.6	15.0	18.6
Cost of maintenance	1.5	4.5	7.5	31.5
Deducting rate for major repair	0.0	0.0	15.0	64.5

in Zhejiang Province (**Tables 2** and **3**).

Substituting the data in formula (1) the costs of patterns II, III, IV relative to pattern I were analyzed through the

$$S12 = 5.97LW - 14.6W - 10.6 \quad (5)$$

$$S13 = 16.05LW - 36.0W - 213.1 \quad (6)$$

$$S14 = 26.85LW - 113.1W - 1634.4 \quad (7)$$

The equations could be applied to calculate the benefits from the labor saving when the average value of labor and areas in a year were known. The critical equations for the economic benefits of the three patterns could be obtained provided that S12, S13 and S14 were assumed to be zero:

$$W2 = 10.6/(5.97L - 14.6) \quad (8)$$

$$W3 = 213.1/(16.05L \times 36) \quad (9)$$

$$W4 = 1634.4/(26.85L \times 113.1) \quad (10)$$

According to the equations (8) to (10), the economic critical curves of grain post-production patterns II, III, IV are shown in **Fig. 1**. With these curves, the critical value of labor in each pattern could be obtained when the operating areas were known. For instance, when the operating areas in a year in each pattern were 10 ha, the critical value of labor in patterns II, III, IV were 2.62, 3.57 and 10.30 yuan/day, respectively, i.e., if the value of labor in an area is more than 2.62 yuan/day and less than 3.57 yuan/day, pattern II is most favourable. When the value exceeds 3.57 and less than 10.30 yuan/day, patterns II and III are favorable. Pattern III, however, is more effective than pattern II because according to the equations (5) to (7), the cost from labor saving in pattern III was better. In other words, with the curves, the critical operating areas in each pattern could also be determined when the value of labor were known in **Fig. 1**. It will be shown that the area on the left of curve II is best suited for pattern I, the area between curve II and curve III is best suited for pattern II, the area between curve III and curve IV is best suited to pattern III, and the area on the right of curve IV is best for pattern IV. In Quier and Quisheng villages, Ning-Xian county, Zhejiang province, the value of labor was 20 yuan/day and the operation areas in a year was more than 10 ha/year. Therefore, pattern IV was most feasible according to the critical curves. In fact, the existing pattern practised here is similar to pattern IV, and shows the most economical effects.

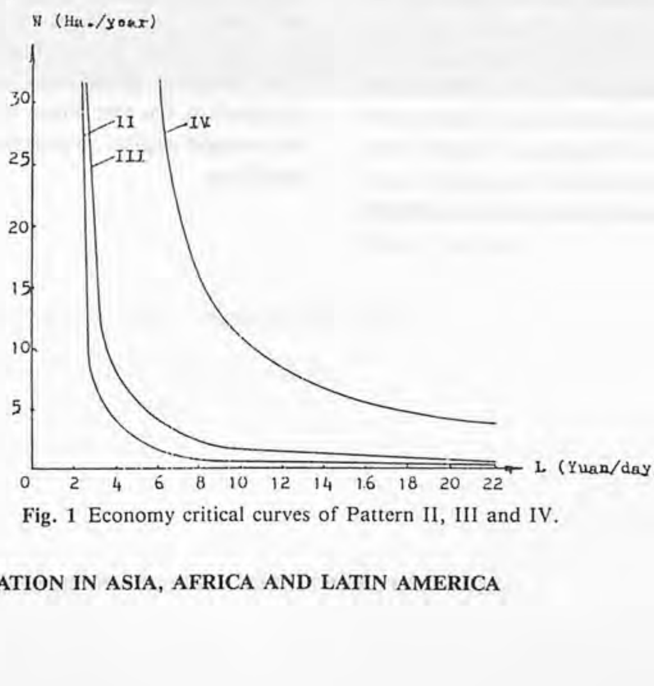

Fig. 1 Economy critical curves of Pattern II, III and IV.

Analysis of Benefits from Increased Productivity or Reduced Losses (s2)

The benefits from increasing

productivity and reducing losses are reflected by the levels of losses. Generally, increasing productivity in post-production system is not visible. Studies in Ningbo, Jinghua and Jianxing with the data collected in 1987 indicate that the losses in pattern I was lowest, that in patterns II and IV were higher, i.e., losses in the operations with machine were higher than that by manual labor (**Table 4**). Therefore, high losses in the operations with machines became one of the important factors which limit the popularizations of the mechanical operations. This must be considered as the machines are chosen for the grain post-production operations. Regarding the functions of machines, the improvements of machines to minimize the losses with high working efficiency are necessary. Meanwhile good machine maintenance and skillful operations would be necessary in order to sustain these improvements.

Table 4 Paddy Losses from Harvesting to Drying at Three Survey Sites (1987)

Item	Pattern I		Pattern II		Pattern IV	
	A	B	A	B	A	B
Yield per ha (kg/ha)	5 453	6 735	6 023	8 205	6 923	7 500
Losses (%)	5.22	4.69	9.09	5.97	6.40	6.00
Losses per ha (kg/ha)	284.6	315.9	547.5	489.8	443.1	450.0

Note: A-First rice crop; B-Second rice crop

Analysis on Benefits from Labor Transfer (s3)

The major benefits from the mechanization of operations in grain post-production were the labor savings. The variable S3 would affect the development of farm mechanization and improvement in grain post-production technologies. For example, with the development of rural enterprises, the economic structures in Quier and Quisheng villages have been remarkably changed. As a result, more labor was required by the enterprises and other side lines. Less labor remained in the production of grains. Therefore, the land was merged into the hands of skillful farmers and a number of specialized farmer households has emerged. The land areas that the farmers managed, therefore, became larger. The labor shortage has become obvious in farming operations. And mechanization of farming, especially in grain production, became the urgent needs. In this case, pattern IV was adopted in these two villages.

In Quier, the labor force engaged in agriculture decreased from 101 to 28. Seventy-three laborers that were saved from farming were shifted to the industries and created a total value of more than 13 700 yuan in 1986. Meanwhile the labor inputs in three harvest seasons annually for the grain harvesting processes were also much reduced and output in these periods from the labor saving in harvestings were as high as about 1 000 000 yuan each year. Pattern IV, however, was not feasible in Jinghua area, Zheijiang province, because the rural industries were not so developed. In other words, there was neither alternatives for the labor transfer nor enough capital to purchase the machines.

Discussions and Conclusion

The adoption of grain post-production patterns which fit into a given area is determined by the reduction of labor input, increase in productivity and minimizing of losses. According to the analysis, four post-production patterns could be applied to the following different areas: Pattern I fits into the area where the economic environment is not ideal with enough labor force to work on farm, the average value per day does not exceeded 2.62 yuan/day: Patterns II and III are better adopted in areas where the technical and economic conditions are moderate with the average value of labor from 2.62 to 3.57 yuan/day and from 3.57 to 10.30 yuan/day, respectively: Pattern IV can be applied to areas where the technical and economic conditions are better and short of manpower with the average value of labor beyond 10.32 yuan/day.

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Surveying of Some Date Palm Parameters and Properties to Be Utilized in Date Palm Mechanization

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Abstract

Materials handling has become more convenient with the use of suitable mechanical devices. Hence, available ability of the physical or mechanical properties of the material being handled is significantly essential, particularly to support the success of any engineering design that deals with any agricultural product.

Only a few or some date palm properties and their characteristics are available in the literature. This is obstacle when input design information is needed.

The objectives of the present work was to provide as many of the date palm properties as possible for use in date palm mechanization. Different measurements were taken on some varieties of date palm in Al-Hassa region: age, tree height, crown height, trunk diameter, palm distribution in the field and cutting resistance of the leaves.

Introduction

Date palm mechanization has become the interest of many investigators lately. Most attempts in such field have resulted in importing machinery equipment hoping that they might have the solution to the date palm mechanization problem. As a result, the market in the Kingdom of Saudi Arabia may have different types of specifications, although none of them has seen the light yet in order to be generalized, or even utilized in some date palm fields. Although date palm mechanization has substantially progressed in other parts of the world like USA (1-5), their technology is not readily transferable unless some major changes in the functional machine design or agricultural practice in Saudi Arabia take place. This is mainly due to the major mismatch between the field conditions and the mobilized machine specifications. This calls for a reconsideration when importing machinery for date palm production and an appropriate technology for the Arabian oases (6).

Agricultural practices in date palm production in the Kingdom have made the mechanization problem an obstacle. Consequently, the solution to the problem of materials handling is a challenge. The difficulties are: non-uniform distribution pattern of palm trees in the fields, different vegetations and intercropping between palm trees, different varieties of date palm at different ages in the same field, and the existence of traditional irrigation distribution canals. These difficulties can put too much constraints on any machine manoeuverability and, consequently, its performance and efficiency. However, having more technical information on the field conditions and related date palm information beforehand can be considered essential. It would ease some of the constraints by giving the designer more input data and more freedom to come up with the most applicable design that suits most of the conditions under consideration.

The objective of the present study was to generate useful information that would help the designers of date palm machineries. The information includes:

1. Height of palm trees.
2. Crown length and circumference of palm trunks.
3. Pattern of distribution of palm trees in the plantation.
4. Leaf cutting resistance of the petioles.

This information was collected from various date palm plantation in Al-Hassa rigion and from different varieties of date palms.

Data Collection

The project was intended to cover several farms in the Al-Hassa oases of Saudi Arabia. The sample farms visited are marked on the general map of Al-Hassa oases shown in **Fig. 1**. These farms are classified as private. In

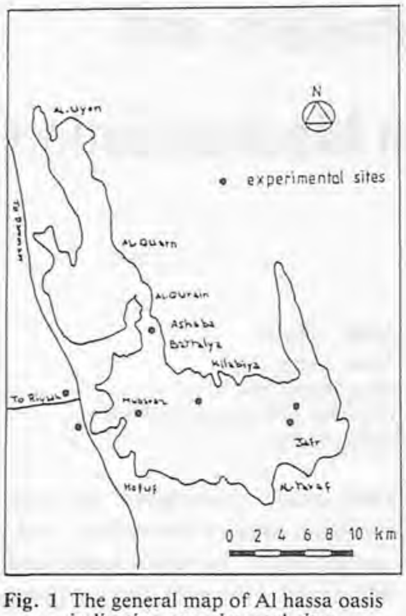

Fig. 1 The general map of Al hassa oasis indicating experimental sites.

general, their degree of care ranged from lightly maintained to poorly cared farms. In each farm, a plot was selected at random for the data collection. A layout was sketched, tree locations were pinpointed, and the condition of the field regarding intercropping, irrigation canals, etc. was recorded. All possible distance measurements between trees were taken by a simple measuring tape to evaluate the distribution pattern in the field. On the other hand, the varieties and ages of all trees within the plot were recorded. Different measurements were also taken on those trees. They include: tree height (measured with an extended aluminum rod that reached the top of the trunk and the crown with a measuring tape, and trunk circumference at three levels from the ground up to 150 cm in height.

Some leaves were collected for the cutting resistance determination. They were obtained from different varieties of palm trees. Three leaves were cut from a single tree, classified to be from tree inside, midway, and at the outer and oldest leaves. Three ten-centimeter cuts were prepared from the petiole for the test. A hydraulic press equipped with a pressure gauge was utilized. A special 2 mm thick sharp edged knife was designed to fit the press for shear application. The cuts of 10 cm from the leaf petiole were used as short beams. Each was based on two metal supports while the shearing action was applied. Readings of the pressure gauge were observed and their maximum values were recorded. The cuts were then over dried at 70°C for 72 h for moisture content determination.

Results and Discussions

Field measurements on the related date palm dimensions are given in **Table 1**. While the data shows wide variations in all the measured parameters, their average values cannot be considered for design purposes. However, the maximum values seem more reliable. Although the maximum tree height shows to be a little over 10 m, the machine working height should reach up to 15 m high to lift an operator to perform the crown related operations. This is to cover all expected height over the life time of the trees. The trunk of a palm tree can be utilized for the machine support, especially the lower 1.5 m height.

Although the tree distances may look spacious in some cases, which encourage the use of a wider machine, intercropping will hinder such encouragement. Moreover, farmers are not comitted to the 10 m spacing between rows or between trees as dictated by the Ministry of Agriculture. Furthermore, the existing irrigation and drainage systems will prevent entering any mobile equipment under existing agriculture practics.

Farms should start an elimination program to adapt their fields to machine use, by getting their fields more organized. This means eliminating all trees that do not fall in straight rows. Irrigation system should be redesigned to accommodate farm mechanization. Irrigation canals should be constructed along the rows only. Subsurface drainage system should be considered.

Cutting Resistance

Fig. 2 shows the variation in the cutting resistance with the moisture content (w.b.) of the leaf (petiole). As the moisture content increases, the cutting resistance decreases. In other words, the drier the petiole leaf, the higher the cutting resistance that the petiole will exhibit. In practice, the oldest and the driest leaves are the ones to be removed in the pruning

Table 1 Date Palm Morphological Dimensions and Distribution in Al-Hassa Farms

Farm #	Height (m)			Crown length (m)	Truck circ. (m)	Tree distances (m)			No. of varieties	Years	Degree of care			
	Max.	Min.	Ave.			Max.	Min.	Ave.			VPM	PM	M	WM
1	7.9	2.8	5.57	1.17	1.64	11.0	5.1	7.8	6	20			*	
2	6.6	2.0	3.73	0.78	1.53	11.8	4.6	7.3	3	23-55			*	
3	10.2	1.1	8.3	0.83	1.70	6.4	3.1	5.8	3	50		*		
4	5.6	3.5	5.10	0.90	1.72	8.7	5.0	6.4	2	18		*		
5	8.0	4.75	7.0	0.68	1.58	7.3	3.9	5.76	2	40	*			
6	8.10	2.15	5.3	1.16	1.37	7.4	2.75	4.83	5	20	*			
7	6.0	1.85	4.5	1.2	1.16	6.2	3.00	4.50	5	30		*		

VPM = Very poorly maintained; PM = Poorly maintained; M = Maintained; WM = Well maintained.

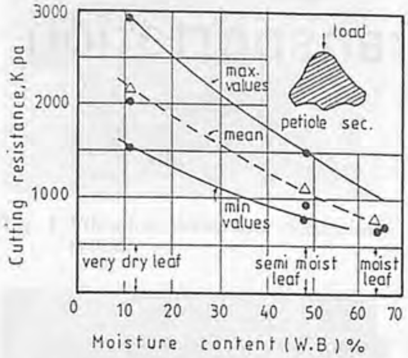

Fig. 2 Cutting resistance of leaf petiole.

operation. On the other hand, while moisture content does not change widely on the same leaf, especially at the petiole base, cutting resistance varies according to the location or distance from the trunk. The closer to the trunk the cutting is, the highest the cutting resistance will be (**Fig. 3**). This is a typical pruning operation where cutting is always applied. Maximum values of 3000 Pa were obtained.

Conclusion

The present work has concluded the following:

1. With respect to the existing old farms, some development have to be introduced such as a) forming straight rows of trees as possible to organize the field, and the irrigation canals should be reconstructed along the rows; b) subsurface drainage system should be included, c) intercropping may be incorporated along the rows, between trees.
2. With respect to the new farms, farmers have to be committed to the 10 m spacing between rows or between trees.
3. Machine working height should reach up to 15 m high, to lift an operator to perform the crown related operations.
4. Palm tree trunks can be utilized for the machine support, at the lower 1.5 m height.
5. Cutting resistance could reach as high as 3000 Pa and an electrical saw can be used for the cutting operation

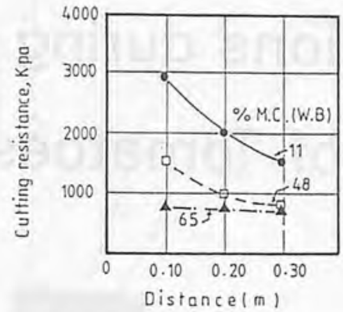

Fig. 3 Variation of the cutting resistance with distance from the trunk.

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Effect of Vibrations during Transportation on the Quality of Tomatoes

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Abstract

Tomato is a major vegetable in India and is easily perishable. During harvest there is glut in the local markets. Tomatoes are transported over long distances resulting in significant spoilage due to vibrations. Basic data in respect of the magnitude of vibrations are not available.

A simple low-cost instrumentation system for low frequency range was designed and developed for measuring vibrations during transportation. Large variations of amplitude against frequency range of 20 Hz to 240 Hz in the form of spectrum was noted between tomatoes as well as boxes. The road condition was reflected by the amplitude or 'g' value indicating the extent of shock received by the tomatoes and hence the quality.

Introduction

Fruits and vegetables contain high moisture content ranging from 75 to 90%. The fresh commodity is, therefore, susceptible to spoilage which is much faster in the summer months than in the winter months. Even 10 to 15% loss of moisture makes it appear stale which also affects the price. India produces about 11% of the world's vegetables and 7% fruits. The farm value of the total fresh fruits and vegetables in India is estimated to be Rs. 225,000 million annually.

At present tomato production in India ranks second only to potato production but stands first as far as processing of vegetable is concerned. This major crop in the Punjab State starts coming to the market towards mid-May and the total span is 4-5 weeks only. At the time of harvesting there is a glut at home and great shortage in distant markets, hence to get good prices, traders and growers send truck loads of tomatoes to their markets.

The major post-harvest problems associated with the tomatoes are the handling and the long distance transport during the month with unfavourable ambient conditions of temperature exceeding 42-46°C and low relative humidity. Apart from the ambient conditions, the vibrations caused to the commodity due to truck transport on Indian roads contribute to serius quality deterioration. Because of the coincidence of peak summer at the time of glut, handling in the field, transportation and storage losses are extremely high. Total loss is approximately 40% of the gross production. On account of the wastage at the rate of 30% the losses incurred are of the order of Rs. 67,500 million (Dalal, 1988). This loss represents an increase over earlier estimate of loss of Rs. 9300 million, (Singh, 1980). On the other hand, O'Brien et al reported fruits transit losses upto 10% in USA and estimated that from half to two-thirds of this loss could be due to vibrations during transport. Average shrinkage due to mechanical damage between grower and consumer is estimated at around 30% on a global scale. Optimum marketing, transport storage and distribution system need to be developed to minimize spoilage and ensure remunerative price to the producer and year-round supply to the consumer. Proper design of truck suspension packaging material and container or boxes will reduce the damage. The intensity of vibrations during the truck transport of tomatoes was measured and their effect on quality of tomatoes is reported in this article. The present study was undertaken with the following major objectives:

1) Development of an instrumentation system for measurement of transport vibrations; and
2) Measurement of vibrations in the transport trucks with tomato packages and inside the packages on the actual road conditions.

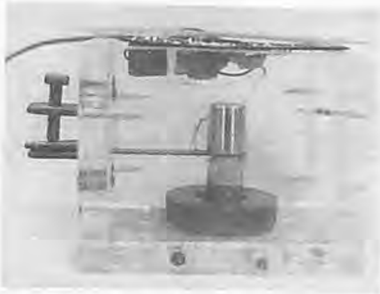

Fig. 1 Vibration pickup instrumentation system.

Fig. 2 Placement of vibration pickup in tomatoes.

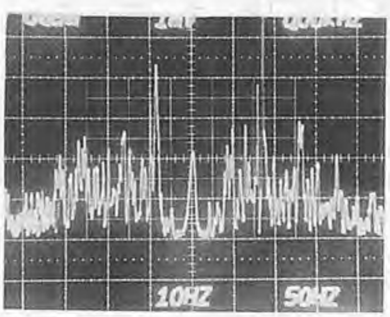

Fig. 3 Frequency-amplitude spectrum.

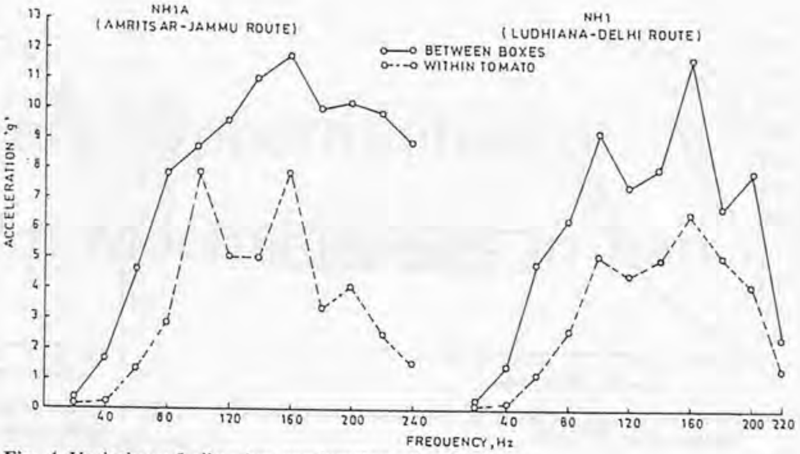

Fig. 4 Variation of vibration acceleration with frequency.

Measurements of Vibration during Transportation

To transport tomatoes to distant places, generally greenish tomatoes are packed in either basket packs of 10-12 kg or in wooden boxes of capacity 18-20 kg after sorting out good tomatoes from the lot as picked from the fields. For the measurement of vibrations, on actual road conditions, the vibration pickup instrumentation system especially designed and developed **(Fig. 1)** for the purpose was used. Vibrations between box to box and within tomatoes were measured. Box to box vibration measurement were made by fixing the instrument to the base of the box and afterwards packing the box with tomatoes as usual. A single layer of newsprint paper is generally placed in boxes, as is clear from **(Fig. 2)** before filling in tomatoes. The second unit of the instrument was placed within the tomatoes in separate box **(Fig. 2)** for measurement of vibrations among tomatoes packed in box.

Boxes thus packed with fresh tomatoes were placed on truck and transported to a distance of 200 km on National Highway 1A. The second set of vibration data was obtained while transporting tomatoes to a similar distance on National Highway 1. Second-set tomatoes harvested manually from PAU farm were graded and packed in the boxes with instrumentation installed in the same manner as in the first case. The data on vibrations was then recorded on the cassettes and reproduced on the spectrum analyzer in processed form.

Analysis of Data

Analysis of data was carried out on spectrum analyzer and storage oscilloscope. Results obtained on the screen of storage oscilloscope were noted visually as well as photographically **(Fig. 3)**. Photographs were taken with the help of a sophisticated camera, attached to the screen of the storage oscilloscope. One division on horizontal scale represents 50 Hz and one vertical division represents 1 mv of amplitude. The representative data has been noted by visual observation at 20 Hz frequency interval. The road conditions determine the magnitude of vibration's acceleration 'g' to the fruits. These accelerations generated at the road surface are transmitted to the fruit through truck chassis and suspension system. The values of 'g' at varius frequencies have been plotted as shown in **Fig. 4** for both routes. As evident from these figures, generally the boxes experienced higher 'g' than the tomatoes. As a result the tomatoes within the container receive lesser shock than the container itself.

Effect of Vibrations on Tomato Quality

The effect of vibrations on the quality of tomatoes was seen from the firmness values obtained on the Instron Universal Testing Machine. The values of firmness of control (vibration free) sample transported samples for NH1A are reported in **Table 1**. Firmness of tomatoes decreased as the storage period increased. The decrease in firmness over 8 days was 2 kg for Kesari variety. Control samples exhibited higher values of firmness as compared to transported samples over a distance of 200 km. This is evident from the fact that the samples were subjected to

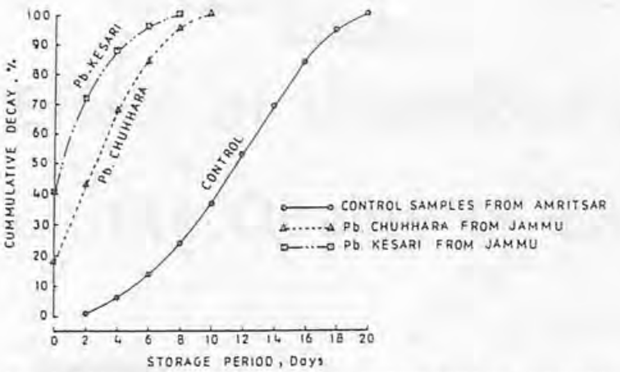

Fig. 5 Effect of storage on decay of tomato samples, Amritsar-Jammu route (NH1A).

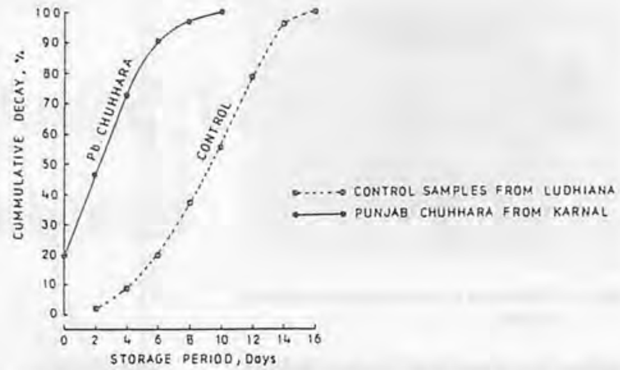

Fig. 6 Effect of storage on decay of tomato samples, Ludhiana-Delhi route (NH1).

severe vibration acceleration during transportation. The firmness of Punjab Kesari (round type) variety is generally lower compared to Punjab Chhuhara (pear shaped) variety under similar conditions. Apart from the decrease in firmness due to vibrations, the decay of the transported samples also appear to be very high as can be seen in **Fig. 5**. Decay in round shaped tomato fruits was very high as compared to pear shaped variety and least in control sample. The results are in close agreement with the findings of O'Brien et al (1963). According to O'Brien the damage to pear-shaped tomatoes is slight as in the case of Punjab Chhuhara and standard round variety as in Punjab Kesari, suffers considerable damage during simulated transit treatments and storage.

Firmness values of tomatoes follow similar trend on NH1 as in case of first route. In this case also, the transported samples cover the same distance of 200 km up to Karnal on the way to Delhi. Decrease in firmness over 8 days period was 3 kg for control and 5 kg for Chhuhara variety. The reduction in firmness values for samples on NH1 is higher as compared to the samples from first route. This is contrary to expectations because NH1 route is smoother and supposedly attributes less shock to the commodity, as is clear from **Fig. 4**. However, the extremely unfavourable ambient conditions prevailing at the time of transportation on NH1, may have casused the softening of tomato samples. For example, the maximum dry bulb temperature at the time of second trip was 43°C and during first trip was 37°C. A referrence to **Fig. 6** reveals that decay of transported samples from NH1 was much higher compared to control sample. the percentage of decay was slightly higher compared to other route samples.

Table 1 Average Values of Firmness (kg) at End of Storage Period, 200 km Transported Samples

Sample	Storage period, days								
	0	2	4	6	8	10	12	14	16
Control for NH 1A	6.1	5.7	4.9	4.4	4.0	3.5	3.2	2.8	2.4
Sample from NH 1A Punjab Chhuhara	6.1	4.9	4.3	3.4	3.0	2.4	—	—	—
Sample from NH 1A Punjab Kesari	6.1	4.1	3.6	2.8	2.2	1.9	—	—	—
Control for NH 1 Punjab Chhuhara	6.8	6.1	5.2	4.5	4.0	3.3	2.8	2.1	1.8
Sample from NH 1 Punjab Chhuhara	6.8	3.3	2.9	2.3	1.8	1.6	—	—	—

The values are average of 3 to 5 replications: Loading rate: 5 cm/min. Deformation 1.0 cm; Average dimensions of tomatoes: L-6.1 cm D-3.9 cm.

Conclusion

Large variation of amplitude was noted against frequencies and also throughout the total frequency span. The magnitude of vibration acceleration within the tomatoes and among the boxes differ significantly. Tomatoes receive less jerks 'g' compared to the boxes. The Punjab Chhuhara tomato variety is suitable for long distance transportation with regard to the quality as compared to Punjab Kesari variety. With an increase in storage period of tomatoes the firmness decreased and decay rate percentage increases.

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Challenges and Opportunities of Dryland Farm Mechanization in Iran

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Abstract

Average crop yields from dryland areas in Iran are low at 750 and 850 kg/ha for wheat and barley, respectively. The Government of Iran in its forthcoming five-year plan (1990-95) has set a high priority for wheat production with yield target of 1 150 kg/ha: an anticipated yield increase of more than 50% over current per hectare yield. This paper highlights soil moisture conservation, seedbed preparation, and seeding methods, along with the adoption of drought-tolerant crop varieties, as major constraints limiting increased crop production in the dryland areas of Iran.

Status of Agriculture in Iran

The country lies between 25° and 40° North latitude and between 44° and 64° East longitude. The country has roughly 165 million ha of land area with an approximate 55 million human population. Although figures vary but according to one recent report (1) compiled by the Agricultural Engineering Research, Testing and Training Centre at Karaj, there are approximately 17 million ha of land under cultivation, of which 5 million ha was irrigated and 12 million ha dryland. Out of dryland area 6 million ha were under crops in crop-fallow-crop rotation in any one year. Major proportion of the irrigated land was devoted to strategic crops such as wheat (52%), barley (18%) and rice (12%). In the dryland areas wheat (70%), barley (22.5%) and pulses (5.5%) were the dominant crops (2). Overall wheat and barley covered 83% of total cropped area **(Table 1)**.

Two Ministries share the mandate of agricultural R&D and extension in Iran. The Ministry of Agriculture and Natural Resources concentrates it's efforts in the irrigated area whereas the Ministry of Jehad Sazandegi is responsible for dryland agricultural development as a part of its rural reconstruction crusade.

Soils

The soils of Iran where dryland farming is mainly practiced, are part of Group 2 (3) under soil classification (3). These soils are nearly level to gently sloping soils of foothills or inter-mountain valleys. These soils are medium to deep-moderately permeable with low organic matter and available phosphorous but contain plentiful calcium. In general because of gentle slope, water runoff is minimum except during heavy rains, although these areas do receive runoff water from higher slopes. The soils are sown to cereals usually in rotation with fallow or in ley farming.

Climate

Iran's climate is classified as predominantly arid and semi-arid. Dryland agriculture is practiced in dry sub-humid regions with 250-500 mm of annual pre-

Table 1 Area under Cultivation of Main Agricultural Crops by Type of Irrigation in Iran (1 000 ha)

Crop	1981-82			1986-87		
	Irrigated	Non-irrigated	Total	Irrigated	Non-irrigated	Total
Wheat	2 055	4 070	6 125	2 310	4 099	6 409
Barley	494	1 071	1 565	822	1 318	2 140
Rice	459	—	459	522	—	522
Sugarbeat	142	—	142	177	—	177
Cotton	146	49	195	149	38	187
Oilseeds	34	58	92	59	39	95
Pulses	108	96	204	163	326	489
Total*	3 641	5 458	9 099	4 456	5 835	10 291

*Includes other minor crops as well.
SOURCE: Centre for Agricultural Statistics and Information, Ministry of Agriculture and Natural Resources, Islamic Republic of Iran.

cipitation and wide range of temperatures. In these areas which are approximately 17% of total land surface of Iran, evaporation highly exceeds precipitation. Monthly rainfall and mean temperatures suggest that most of the precipitation is in the form of snowfall in winter and the rains mainly occur in the early spring season except in the Caspian Sea area where rainfall is much higher and well spread throughout the year. In most places maximum temperatures exceed 40°C whereas in winter these are below freezing point.

Cropping Patterns and Yields

Because of low rainfall, crop intensity is low with one crop every two years. Crops are rotated with fallow or grown in lay farming in drylands. Overall productivity of crops is low at 1 172 kg/ha for wheat and 1 291 kg/ha for barley (**Table 2**). These yields although low, have increased during a five year period between 1981-82 and 1986-87 by 8.6% and 20% in case of wheat and barley, respectively. These increases are said to have been associated with the increased use of better seed, and with soil moisture conservation. In dryland areas, mean wheat and barley yields are 750 kg/ha and 850 kg/ha, respectively. It is interesting to note that yield of pulses has actually declined by 21% in five years between 1981 and 1986. This should be a matter of serious concern for the authorities.

Table 2 Productivity of Major Agricultural Crops in Iran

	Total yield (1 000 ton)			Yield per unit area (kg/ha)		
	1981-82	1986-87	Percent change	1981-82	1986-87	Percent change
Wheat	6 610	7 400	12.0	1 079	1 172	8.6
Barley	1 700	2 762	62.5	1 076	1 291	20.0
Rice	1 624	2 094	26.2	3 538	3 925	10.9
Sugarbeat	3 231	4 965	53.7	22 753	28 051	23.3
Cotton	275	345	25.4	1 441	1 845	30.8
Oilseeds	84	127	51.2	965	1 344	39.3
Pulses	290	370	27.6	956	756	20.9(−)

SOURCE: Centre for Agricultural Statistics and Information, Ministry of Agriculture, Islamic Republic of Iran.

Status of Dryland Agricultural Mechanization

Seedbed Preparation

Within the current practice of crop-fallow-crop rotation, the land is usually ploughed with moldboard in autumn after cereal harvest in June/July. Statistics (1) suggest that although 59% of the total farmers in Iran own moldboard ploughs, only 5% own the machine in drylands. The ploughed land is wintered-over and during spring the fields are normally cultivated twice with disc or sweep type cultivator to destroy weeds and pulverize the soil. No further field operations take place until autumn.

The tillage operations are mainly (90%) mechanized, with some animal-drawn implements being used in peasant farming in hilly areas.

Seeding and Fertilizer Application

Seeds and fertilizer are generally broadcast using fertilizer spreaders or by hand in anticipation of autumn rains. Seeds and fertilizers are covered by shallow disking. Only 2% of the farmers are known to own seed drills whereas 1% of farmers have fertilizer spreaders (**Table 3**).

Seed rates for wheat and barley are usually at 50 kg/ha although up to 70 kg/ha of seeds are also recommended in slightly high rainfall (350-400 mm) areas under dryland agriculture. Fertilizer application rates average 50 kg/ha in the form of ammonium phosphate with N and P ratio at 18:48.

In the dryland areas, the use of machinery varies according to the socio-economic conditions of farmers. For example, in the Gazvin and Takistan areas, 93% of farmers broadcast seed by machine or by hand whereas in Hamadan area up to 50% farmers are known to use seed drills.

Table 3 Percent of Farmers Using Selected Implements

Implement	Percent
1. Moldboard ploughs	59
2. Disc harrows	38
3. Thresher-cum-cleaners	49
4. Trailers	26
5. Knapsack sprayers	14
6. Power sprayers	6
7. Ditchers	4
8. Combine harvesters	12
9. Seed drills	2
10. Tillers	13
11. Fertilizer distributors	1

SOURCE: RNAM Country Report of Iran, 1988.

Crop Protection

At present, little or no crop protection measures are observed except seed treatment with fungicides before sowing. If serious disease or pest problems occur, the Government helps by aerial spraying the affected areas without costs to the farmers.

Crop Harvesting

Wheat and barely threshing is almost 100% mechanized or partially mechanized in Iran. Nearly 50% of the farmers are known to own grain threshers and about 12% use combine harvesters (**Table 3**). The agricultural cooperatives such as the combine owner's cooperative have been successfully helping the harvesting processes.

Economics of Cereal Mechanization

The continuous migration of

rural populace to cities and drudgery of farm labour have indirectly helped the cause of agricultural mechanization in Iran. These factors combined with high beef prices have encouraged farmers to buy or use machinery on rental basis from individual farmers or through cooperatives for use in difficult farm operations. However, because of decreased imports and shortage of raw material for local production of machinery, rental charges and cost of machinery have increased rather steeply in recent years.

Table 4 Cost/Benefit Ratio of Growing Dryland Wheat, Iran, 1989

Farm operation and input	Cost (Rls/ha)	Cost (US$/ha)
1. Moldboard ploughing	5 000	67
2. Sweep-type tine x 2 passes	7 500	100
3. Seeding (by fert. spreaders)	1 500	20
4. Fertilizer application	1 500	20
5. Disking (to cover seed and fert.)	2 500	34
6. Plant protection	N/A	N/A
7. Combine harvesting	10 000	133
8. Seed of 70 kg/ha @ Rls. 130/kg	9 100	121
9. Fertilizer (Ammonium phosphate at 50 kg/ha Rls 11/kg)	550	7
10. Transportation of inputs	3 000	40
Total:	40 650	542
Grain value of 750 kg/ha @ Rls 100/kg	75 000	1 000
Profit /ha**	34 350	458
Profit/ha/year***	17 175	229

* At an official exchange rate of US$ = 75 Rials. However, the open market rate of exchange is US$ = 1 400 Rials
** Excluding labour costs and other incidental costs.
*** On the basis of one crop every two year in crop fallow rotation in drylands.

A cost/benefit analysis (**Table 4**) for the production of wheat from drylands suggest that farmers must produce at least 406 kg/ha to break even. This excludes farmers' own labour input. A small farmer with 5 ha of land (over 70% land holdings in Iran are less than 5 ha) can expect to earn an average Rials 7 000 per month. This is approximately 1/4 of what an unskilled labourer earns in the town/city. In dollar value this earning is approximately US$93 at the official rate of exchange, or only US$5.00 per month at open market exchange rate. The latter is more realistic as the values of inputs are close to these rates.

Status of Agricultural Machinery Manufacturing

Manufacturing Capabilities

There are no reliable statistics available on the number of machinery manufacturers in Iran. A guess suggests that there are around three hundred of them ranging from small workshops (artisans) to medium and large size manufacturers such as tractor and combine harvester companies. Most medium and large size enterprises appear to be in the public sector. Major centres for agricultural machinery manufacturing are in Tabriz, Arak and Karaj/Tehran areas. Most tractor assembly and manufacturing is concentrated in Tabriz where Universal 650 and MF 285 tractors are produced under license. About 7 000 power tillers (single axle tractors) are produced annually under license from Mitsubishi and Kubota of Japan. Since the local production of power tillers does not satisfy the market demand, another 5 000-7 000 units are imported annually. The power tillers which range from 4.5 to 13.0 in hp are used mainly for puddling and seedbed preparation in rice lands.

The Combine-Sazi factory in Arak is manufacturing John Deere Combine (JD-955) and balers under license from West Germany. Up to 83% parts by content and 66% by value are locally manufactured whereas electrical and hydraulic systems were imported. The Government of Iran is also encouraging private local agricultural machinery manufacturers to meet local demand in a drive towards self-sufficiency. The types of equipment and numbers are known to be produced locally (**Table 5**).

Table 5 Annual Implement Manufacture, Iran

Implement	No. Manufactured/Year
Moldboard ploughs	15 000
Disc harrow frames	1 000
Disc harrow blades	60 000
Thresher-cum-cleaners	7 000
Agricultural shovels	120 000
Cultivators	3 000
Ditchers	1 000
Border ridgers	1 000
Knapsack sprayers	25 000
Wheelbarrow-type sprayers	10 000
Trailers (2 and 4 wheel)	500
Power-tiller ploughs	10 000
Power-tiller ridgers	3 000
Fertilizer distributors (centrifugal)	350

SOURCE: RNAM Annual Country Report of Iran 1988

Constraints

During visits to selected machinery manufacturing enterprizes and through interviews with their management, it became clear that almost all manufacturing units were running much below their capacity and some were running at a loss. This was mainly due to:

a. Low supply of raw material at controlled prices.
b. Foreign exchange difficulties
c. Lack of export opportunities

These difficulties were not unexpected for a country which has been through major difficulties over 10 years. Low supply of raw material was indeed the major constraint faced by all respondents. The Government normally supplies the raw material at controlled prices, and buys back the output through its Bongah system for supply to farmers on predetermined priorities based on factors such as the size of land holding and potential for farm output.

Conclusions and Recommendations

1. Wheat and barley are the predominant crops grown covering 93% of 6 million ha under dryland agriculture every year in Iran. Yields are, however, low at 750 and 850 kg/ha, respectively.

2. There is a yearly deficit of about 1.8 million tons of wheat which is imported. Therefore, the government places a high priority on self-sufficiency in this crop because of its strategic importance.

3. Major constraints to increasing yields are soil moisture deficit, inadequate cultural practices and lack of drought-resistant seed varieties.

4. There is an urgent need for developing and popularization of soil moisture conservation equipment such as chisel ploughs, sweep type cultivators, scarifiers and ridgers, and seed-cum-fertilizer drills for improvement in crop establishment and fertilizer use efficiency.

5. Current R&D activities in the dryland crop production system particularly relating to agricultural mechanization are minimal, although it appears that the ministry of Jehad Sazandegi currently having the mandate of dryland agricultural development, is planning some steps to rectify this situation.

6. There is a general shortage of trained professionals in the agricultural machinery R&D and mechanization in the country.

7. The Agricultural Engineering Research, Testing and Training Centre at Karaj has at present very little local R&D underway, although the centre is doing relatively well in the testing and training aspects. The centre needs a major update in laboratory equipment, and training of professionals both at master and Ph.D. levels to enhance its R&D capabilities.

8. Local manufacture of selected equipment is a prerequisite to achieving widespread impact on dryland crop production. However, because of shortage of raw materials which is a major constraint to current gap between demand and supply of machinery, almost all medium to large machinery manufacturers have spare capacities. Most of these enterprises were prepared to undertake joint development work and mass production, provided the raw material was available and technical assistance was forthcoming for new equipment.

9. A Dryland Agricultural Research Centre should be established, or the one at Takistan modernized. Such a centre should include major emphasis on dryland agricultural mechanization.

10. The dryland areas of Iran have the most potential for helping increase crop productivity of strategic crops for self sufficiency as well as for promoting the economic thresh-hold of rural communities. Therefore, steps should be taken to exploit the dryland soil resources on sustained basis.

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Simulation Model for Poultry Ventilation Rates and Supplemental Heat in Winter

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Introduction

It is widely acknowledged that in many cases, animal production is reduced by stress imposed on the animal by environmental, nutritional, pathological and other factors. The ventilation system is the vehicle by which the indoor environment is determined. The role of the ventilation system is quite complex because of the interactive influences it has on disease, nutrition, noxious gases, dust, space and other unrecognizable factors as well as on the thermal environment. These factors singly or synergistically are likely to greatly affect growth, production, reproduction, behavior and, ultimately, the profit of the livestock enterprises.

Optimization of agricultural ventilation system designs for energy conservation requires consideration of fans and motor efficiencies, effect of climatic variations on air delivery rates and patterns, effect of ventilation rates and stock density on supplemental heating requirements, ventilation rates and distribution on biological performance, long term effects of the environment on ventilation system, and building construction features (insulation).

Environmental factors are generally recognized to have a major impact on the production of meat and eggs from poultry. These include temperature, humidity, light (length of day and intensity), air velocity (air movement), solar energy, quality of air, water and density of population.

Literature Review

Two of the main purposes usually given for ventilating poultry houses are temperature control and removing excessive moisture. These two factors are especially important during critical high temperature periods. Winn and Godfrey (1967) showed that high temperature depressed broiler growth and high temperature combined with high relative humidity further depressed the growth rate. Ota and McNally (1961) showed that sensible heat production from broilers decreased to a relatively low level per chick when the ambient temperature in the house was in the range of 33 to 35C. Esmay et al. (1968) showed that ventilation rates as well as outside dry and wet temperature, affected the dry bulb temperature of the exhaust air from commercial windowless laying houses during the high temperature period of summer days.

In winter the warmer and drier the shelter, the less the complications of wet litter, disease, dirty eggs and deterioration encountered. For winter use the house should be insulated in order to permit the removal of at least the respired moisture while maintaining the house temperature at optimal level. The ventilation system should have capacity and flexibility to dry out the house during warm periods and maintain desired temperature in winter.

Objectives

The objectives of this study are to:

1. Construct a simulation model to determine ventilation rates for poultry buildings and that include ventilation rates, temperature, moisture and minimum ventilation rate.
2. Determine the ideal ventilation rate and supplemental heat requirement for a given building.
3. Determine the graphical output of ventilation rates, ideal ventilation rate and supplemental heat.
4. Calculate the cost of using different fuels for supplemental heat, including L.P. gas, kerosene, and electricity.

Methods

The basic form of the equations used to determine air flow rates has been used in many types of the engineering analyses for many years. Under steady state conditions, the law of conservation of energy and mass can be simplified as

Quantity in = Quantity out (1)

Several simplifying assumptions were made to develop the model: No heat storage in the building; Complete mixing of the air within the building; and Constant heat and moisture production of poultry during the time interval.

The systems defined by this research are the environmental conditions surrounding the poultry and enclosed by the interior surfaces of the animal shelter. A sensible heat balance equation can be written as.

$$q_s + q_e + q_{sup} = q_b + q_{sv} + q_w \quad (2)$$

where,

q_s = Sensible heat produced by poultry in W

q_e = Sensible heat produced by equipment such as motors, lights, etc. in W

q_{sup} = Supplemental heat used in W

q_w = Sensible heat released by condensation of water vapor (+) or utilized to evaporate moisture (−) within the building in W

q_b = Heat loss through the building walls, floor, ceiling, and windows in W

q_{sv} = Sensible heat loss through ventilation in W

The number of terms of equation (2) can be reduced by neglecting the heat produced by the equipment and heat released by condensation of water vapor when it is very small in comparison with other heat inputs.

The building heat loss q is determined from

$$q_b = A \times U \times (t_i - t_o) \quad (3)$$

where,

A = area of walls, ceiling, and windows in m^2

U = overall conduction heat trans. coefficient W/m^2 C

t_i, t_o = inside and outside air temperature in C

To solve for the ventilation rate needed to maintain the inside air temperature at a specified temperature without supplemental heat (set to zero). Since ventilation is normally expressed as m^3/s.

$$Q_s = [v/C_p \times (t_i - t_o)] \times (q_s - q_b) \quad (4)$$

where,

Q = ventilation rate for temperature control m^3/s

v = specific volume of air, evaluated at inside conditions for exhaust system in m^3/kg dry air

C_p = specific heat of air (1.0035), kJ/kg C

If the ventilation rate for a building has been selected, equation (2) can be used to determine the amount of supplemental heat needed in the facility by solving for q_{sup}.

$$q_{sup} = q_{sv} + q_b - q_s \quad (5)$$

The heat loss through ventilation q_{sv} is determined by the following equation.

$$q_{sv} = C_p \times M \times (t_i - t_o) \quad (6)$$

where,

M = ventilation air mass in kg/s

$$M = Q_s/v \quad (7)$$

A similar procedure, based on moisture or latent heat balance, can be used to develop an equation to compute the ventilation rate necessary to remove the generated moisture and thus maintain a predetermined humidity ratio within the shelter. The resulting equations are:

$$Q_l = (v \times M_w)/(W_i - W_o) \quad (8)$$

$$M_w = q_l/2430 \quad (9)$$

where,

Q_l = ventilation rate for moisture, in m^3/s

M_w = rate of water vapor production in the building, in kg H_2O/s

q_l = latent heat produced by animals in kW.

2430 = latent heat of vaporization of water at 30 °C, body surface temperature in kJ/kg water

W_i = humidity ratio of inside air, kg water/kg dry air

W_o = humidity ratio of outside air, kg water/kg dry air

Ideal ventilation rates for agricultural applications usually are determined by the interaction of multiple variables. This results in a series of ventilation rate regimes in which the ideal ventilation rate is determined by limitations of different variables within each regime.

In poultry buildings, the ideal ventilation rate is determined by three control regimes (in winter) as shown in **Fig 1**. These regimes are ventilation rate for temperature control, ventilation rate for moisture control, and minimum ventilation rate for population.

Results

This model could be used effectively to evaluate and test different strategies, insulation, building size and bird density. One of the important factors in construction of poultry house is how much insulation is needed to help provide birds with optimum environment in winter, especially to lower heat loss through the building and to prevent water condensation on the walls and ceiling.

The main purpose of this model is to calculate the ideal ventilation rate and estimate supplement heat. Many poultry producers do not give ventilation rate any importance. They usually use high ventilation rates which could lead to high fuel consumption, and lower fan life (wear out). Using proper ventilation rate will lead to better air mixing and temperature distribution for more comfort.

The model could be used to evaluate and select the right amount of insulation material, size and bird density for new constructed poultry houses. In the same token, from the ventilation rate calculated for the new building, a ventilation system, number and type of fans can be selected.

A typical poultry house in subtropical region (near Baghdad) has size 70 × 11 × 2.5 m with wall insulation 1.9 and ceiling insulation 0.98 W/m^2 C. With full bird capacity of 10 000 birds, average weight of 1.6 kg **(Fig. 1)** could save on fuel consumption by increasing wall and ceiling insulation. This could be justified for long operation of poultry house.

This also prevents water condensation on the wall, ceiling and equipment. Improving environmental conditions by providing optimum temperature will improve feed consumption.

For hen house, typical for cold region with size 33 × 11 × 2.3 m wall insulation 0.54 and ceiling insulation 0.32 W/m^2 °C with four-tier cage system. The model shows that it is not necessary to use supplemental heat for − 20 C. The amount is very small and cannot justify the investment in heating equipment. In this situation inside temperature could drop down a few degrees, but this could be improved by lowering minimum ventilation rate (Alchalabi, 1986).

VENTILATION RATE FOR POULTRY
Designed by Dr. Dhia Alchalabi

Information about building

Length in m ? 70
Width in m ? 11
Hight in m ?2.5

Information about insulation

Walls in W/m^2, °C ? 1.9
Ceiling in W/m^2, °C ? 0.98

Information about environment

Inside temperature	°C	? 20
Inside relative humidity	%	? 70
Outside relative humidity	%	? 80

POULTRY
1-Hens 10 ~ 28°C
2-Broilers 10 ~ 30°C
3-Turkeys 10 ~ 30°C

Choose one option please ? 2

FUEL USED IN ID/L

Price of L, P. Gas	? 0.062
Price of Kerosene	? 0.040
Price of Electricity	? 0.012

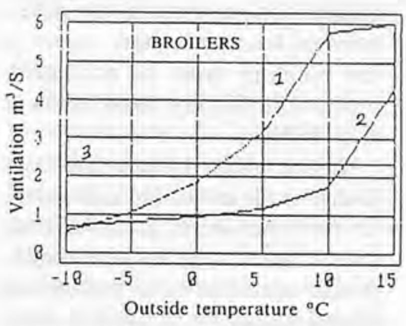
College of agriculture

BROILERS

1-Chickens (1.1 kg) 16-30°C
2-Chickens (1.6 Kg) 19°C
3-Chickens (2.0 Kg) 19°C

Choose one option please ? 2
Number of Chickens ? 10 000

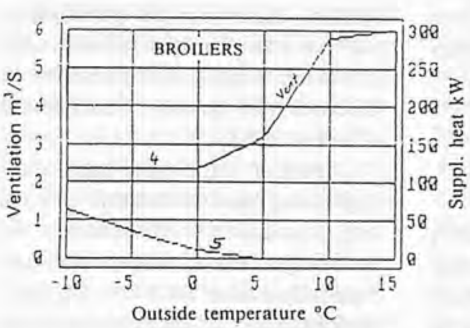
Ventilation rates for poultry



Ventilation rates for moisture and temperature

°C	m^3/s	m^3/s
− 10	0.84	0.64
− 5	0.91	1.15
0	1.04	1.92
5	1.27	3.20
10	1.82	5.75
15	4.35	13.43

Min ventilation rate	2.40
Length of the building	70 m
Width of the building	11 m
Hight of the building	2.5 m
Walls insulation	1.9 W/m^2, °C
Ceiling insulation	0.98 W/m^2, °C
Temperature inside	20°C
Rel. humidity inside	70%
Rel. humidity outside	80%



Ideal ventilation rate and supplemental heat

°C	m^3/s	kJ/s
− 10	2.40	62.75
− 5	2.40	37.09
0	2.40	11.43
5	3.20	0.00
10	5.75	0.00
15	13.43	0.00

Fuel Cost in ID/h

L P gas, heater eff. 70%	0.011
Kerosene, heater eff. 70%	0.005
Electric, heater eff. 90%	0.020
Rel. humidity inside 70%	
Temperature inside 20°C	
Number of chickens	10 000 Birds

Fig. 1 Ventilation rate for poultry.

(Continued on page 84)

Comparison of a Conventional vs a Heated-hallway Swine Production System

by
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Abstract

The need for proper usage of energy in livestock buildings is especially important for intensive swine production. Presented here is an economic comparison between a conventional and a heated-hallway swine production systems. The total seasonal heating and ventilating requirements were calculated in order to determine fuel and electricity consumption. The results indicate that the cost of heating energy used was around 11% more expensive in the conventional system. A saving of 15% in the cost of electricity were realized in the heated-halfway building.

Introduction

There are several reasons why livestock buildings have to be ventilated. One of the most important reasons is that the oxygen consumed by the animals has to be replaced. Livestock produce various quantities of heat and moisture. Animals also produce water and noxious gases that must be eliminated. Some additional moisture is evaporated from moist litter and wet surfaces in the building. Moreover, the temperature of the bulding has to be maintained as constant as possible, depending on extreme weather conditions in order to prevent an undesirable temperature drop. For design and operation of an effective environmental control system, the quantities of heat and water vapor in the building must be accurately predictable (Esmay, 1978; Barre et al., 1988).

In the winter time, a livestock shelter tends to be cold and damp. On the other hand, in the summer time, it tends to be hot and humid. A near-optimum environment can be maintained by means of a well-designed controlled ventilation system, otherwise the production rate of the animals related with growing, weight, and presence of diseases will get to critical levels (Curtis, 1983).

Another important parameter regarding environmental control are insulation requirements of buildings which have changed radically since 1973 — the first energy crisis. As energy costs have increased so has the amount of insulation being placed in walls, floors and ceilings. Thermal insulation can be defined as a factor that reduces heat transfer from one area to another. The amount of conduction heat loss through the exposed surfaces can be manipulated by varying the amount of insulation, shape of the building, and inside temperature (Esmay, 1978).

Since modern swine production facilities require efficient environment control with minimum energy expenditure, it is interesting to look at ventilation control designed to provide just enough ventilation air exchange to remove the excess moisture from the building.

The trend in the use of intensive methods of hog raising is still on the increase. It is important, therefore, to examine the benefits that may be expected from keeping pigs in a particular controlled environment.

The proper design of livestock buildings has always required a well controlled air distribution system. Conventional systems that utilize building components such as slotted inlets improve the functional requirements of heating and ventilation by means of introducing some additional building improvements.

The objective of this study was to compare the economics of a heating and a mechanical ventilation system for farrowing and nursery units against a conventional and a heated-hallway building.

Antecedents and Data

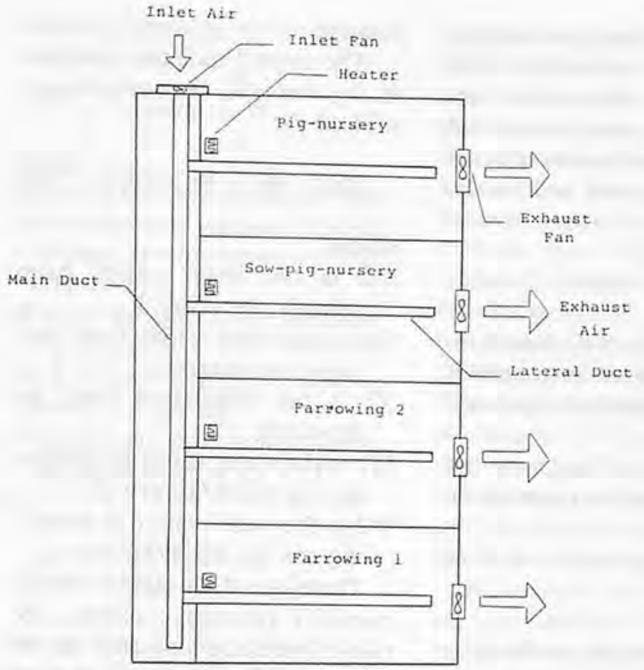

Fig. 1 Neutral ventilating scheme of the conventional system.

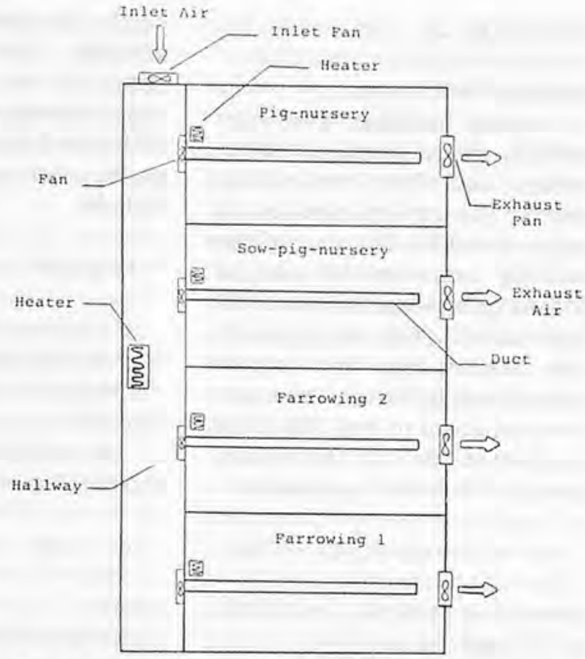

Fig. 2 Heating and ventilating scheme of the heated-hallway system.

Farrowing

The stalls were 1.5 m wide by 2 m long. The number of sows per stall was one, so the total number of sows in each farrowing room was 20 sows with litters on partly slotted floors, with which labor was greatly reduced in removing materials.

The requirements of temperature for sows and young nursing pigs differ from each other. The first three days of life a newborn pig needs a dry environment at a temperature of 32°C. On the other hand, a sow requires an environment at 16-18°C. In fact, it is adequate to provide these two ranges of temperatures in order to keep the farrowing room at 18-24°C, and supplying supplemental heat in the creeps with infrared lamps (Midwest Plan Service, 1983). In this case, a temperature of 21°C was used in the calculations.

According to the Midwest Plan Service (1983) in a farrowing house it is necessary to provide a heating capacity of around 1172 W each sow and litter.

Nursery

A sow-pig nursery room is used to relocate sows and their 3-day to 3-week-old litters from the farrowing unit. In general, in totally or partly slotted sow-pig nurseries, a minimum pen size of 1.5 m × 3 m for one sow and litter, and 2.4 × 3 m for two is usually recommended. In a pig-nursery the space requirement is 0.3-0.4 m^2 per pig for totally or partly slotted pens, where each pen size is good for 16 to 20 pigs weaned at 8 weeks from about 14 kg up to 35 kg each. For the present study 20 pigs per pen of 35 kg weight in partly slotted floor was considered.

For 3-week old pigs, from the time of weaning until they weigh about 5 kg each, the temperature in the room should be around 27°C if a constant temperature is to be maintained in the sow-pig nursery room. For 8-week old pigs, in the pig-nursery room, the temperature is reduced to a minimum of about 21°C. In this case, a temperature of 24°C was used in both sow-pig nursery room and pig-nursery unit.

A heating capacity of 879 W per sow and litter in a sow-pig nursery room is recommended. Driggers and Jensen (1981) suggest a heating capacity of between 73 W and 88 W for each pig in a nursery.

Heating and Mechanical Ventilating System

Mechanical ventilating systems employ fans to move air through the animal buildings by means of electrical energy. Neutral pressure system includes inlet shutters, air distribution ducts, a duct fan, and exhaust fans. The fresh air enters the duct from the outside by means of a motorized shutter. In the conventional system, the duct fan moves and distributes ventilating air through the main duct and then it enters the lateral ducts where it is heated. After that, the air is exhausted through wall fans located in every independent unit (**Fig. 1**). In the heated-hallway system, the heater is placed in the hallway, hence air entering from outside is heated previously, then enters the ducts and individual rooms (**Fig. 2**).

Building Heat Losses

In every building, heat losses through walls, windows, doors, ceiling, and floor were determined. The rate of heat loss is proportional to the area of the building component (A) and the difference between the inside (Ti) and outside (To) temperatures. The rate of heat flow is also proportional to the total transmission coefficient to heat (U) of the component. It can be written through the following equation:

$$qb = U \times A \times (Ti - To)$$

where qb is in W, U is in W/°C-m^2, Ti and To are in °C.

Analysis of Animal Environment: A Review

In planning a ventilation system it is necessary to control all the factors that can influence the ventilation required for type, age and number of pigs, their management, the construction and location of the house and the weather conditions.

What really hapens in a controlled environment building is explained very well by an analysis of both heat and moisture balance.

The temperature is controlled by means of a ventilation process, and so occurs with humidity and odors. In fact, the temperature and the amount of water may have significant variations as a consequence of movement of air into a building.

Basically, an energy balance relates sensible heat gains or input and losses or output to ventilating rate. Latent heat sources and losses to ventilating rate are related in a moisture balance.

The building must be maintained at an inside temperature within the comfort zone of the animals. As sensible heat produced into the room rises temeperatures, it must be removed at the rate it is produced. In other words, heat sources and losses, includes

$$Q \text{ gained} = Q \text{ lost}$$

If too much sensible heat is removed, temperature drops, and if not enough is removed, temperature rises.

The equation of balance that explains the previous equation is:

$$qa + qm + qh = qb + qv + qe$$

where,

qa is the sensible heat produced by animals
qm is the mechanical heat from lights, motors, etc.
qh is the supplemental heat
qb is the building heat loss
qv is the sensible heat loss in ventilating air
qe is the sensible heat used to evaporate water

In general, qm is neglected because it is relatively small. Similarly, some of the sensible heat produced by animals is used to evaporate water within the building, and it is intermittent, then qe is also generally neglected.

For a given building and animal population, either the ventilating rate is assumed and the needed heater size is calculated or the ventilation rate is calculated knowing previously the supplemental heat. Therefore, the previous equation of heat balance is reduced to

$$qa + qh = qb + qv$$

Moisture evaporated from wet surfaces into the building and from animal breathing must be maintained below 70-80% as a desirable indoor condition. In practice, surface condensation is usually not desirable in animal housing.

The overall moisture balance, in kg water/h, is basically expressed as:

$$Ma + Me = Vr \times (W2 - W1)$$

where,

Ma is the water vapor from animals, kg water/h
Me is the water vapor from surfaces, kg water/h
Vr is the ventilation rate, kg dry-air/h
W1 is the water vapor in exhaust air, kg water/kg dry-air
W2 is the water vapor in incoming air, kg water/kg dry-air

Therefore, if the indoor relative humidity remains constant, the rate of moisture loss must be the same rate of moisture production in order to maintain a desired indoor relative humidity.

Combining both the heat and moisture balances, the ventilating rate to maintain an adequate indoor temperature is

$$Qt = \frac{60 \times v \times (qa - qb)}{Cp \times (Ti - To)}$$

where,

Qt is the ventilating rate, m^3/min
v is the specific volume of air at inside temperature, m^3/kg dry-air
Cp is the specific heat of dry air, 1003.5 J/kg dry-air °C
Ti is the indoor temperature, °C
To is the outdoor temperature, °C
qa is the sensible heat production of animals, W
qb is the building heat loss, W
and

$$qa = Ah \times N$$

where Ah is the sensible heat production of each animal at indoor temperature (W), and N is the number of animals in the room.

Similarly, the ventilating rate to maintain an adequate moisture balance is given by the equation:

$$Qm = \frac{M \times v}{(Wi - Wo) \times 60}$$

where

Qm is the ventilating rate, m^3/min

v is the specific volume of air at indoor temperature, m^3/kg dry-air

M is the moisture to be removed, kg water/h

Wi is indoor humidity ratio, kg water/kg dry-air

Wo is the outdoor humidity ratio, kg water/kg dry-air

and

$$M = \frac{Ma \times N}{675.54}$$

where Ma is the latent heat produced by animals (W/animal), 674.54 is the latent heat of vaporization of water produced at 30°C, body surface temperature (W/kg water), and N is the number of animals.

The latent and sensible heat produced from the animals vary along with their progressive weights of them, and with the type of floor where the animals are placed in the building. In fact, for slotted floors, the sensible and latent heat production is 48.36 and 20.52 W/pig, respectively, considering pigs weighing 14 kg each. On the other hand, when sow litter weighs 180 kg, the sensible heat is 307.76 W/pig while the latent heat is 293.10 W/pig (Midwest Plan Serivce, 1983).

Results and Discussion

In order to calculate the heat and moisture balance, all the previous equations were put in a useful computer program. With that information it was possible to obtain the heat and moisture balances separately.

Thus, the minimum outside temperature that corresponds to the recommended ventilating rate was determined. From the recommendations given by the Midwest Plan Service (1983), values of 17 m^3/min for 14 kg-pigs roomed in pig-nursery units, 9 m^3/min for 180 kg-sow with litter, and 11 m^3/min for sow with litter in farrowings were taken.

In general, the actual ventilating rate indicated that at outside temperatures below the intersection of the minimum winter ventilating rate and the temperature balance curve, supplemental heat was required to maintain the inside needed temperature. At outside temperatures above the intersection point, the inside relative humidity proved to be below the design 80%.

Heating Requirements

A methodology proposed by the Midwest Plan Service (1983) and Hein (1982) for determining seasonal energy usage in animal housing systems was applied here. This procedure is called the bin method. Basically, it consists of performing hourly energy calculations at many different outdoor dry-bulb temperature conditions or temperature bins, and multiplying the calculation by the number of hours of occurrence in each temperature bin.

The hourly weather occurrence values were taken from Table 674-5 of the Midwest Plan Service (1983) for Grand Rapids, Michigan. Results obtained in the conventional system by using the bin method showed that the pig-nursery presents the highest seasonal requirements with 18 209 kW. On the contrary, the unit that has the lowest requirements per season is the sow-pig nursery with 2 471 kW.

Regarding the heated-hallway system, results obtained show that the highest seasonal requirements correspond to the pig-nursery with 16 654 kW, whereas the sow-pig-nursery unit presents the lowest heating requirements with 2 385 kW.

Comparing both systems, the heating requirements per season and per unit of the heated-hallway building were lower than those of the conventional building.

Energy Costs

In **Tables 1** and **2** are shown the costs of the heating and ventilating seasonal requirements. The calculations are based on the cost of liquid propane (20 cents per liter March, 1987), and that its heating value is 25 5597 kJ/l (Hinkle et al., 1981). Then assuming a furnace with 80% of efficiency, the expression is

Hc = (3.6 × Heat requirement × Cost per liter)/(25 559.7 × Efficiency)

Table 1 Heating and Ventilation Requirement Costs per Season for Conventional System

Room	m^3/min	Heat requirements (kW)	Days	Hc (US$)	Vc (US$)
Pig-nursery	17	18 209	171	641	15
Sow-pig-nursery	9	2 471	180	87	8
Farrowing 1	11	8 430	180	297	10
Farrowing 2	11	7 557	127	266	7
Total		36 667		1 291	40

Table 2 Heating and Ventilation Requirement Costs per Season for Heated-Hallway System

Room	m^3/min	Heat requirements (kW)	Days	Hc (US$)	Vc (US$)
Pig-nursery	17	16 655	171	586	15
Sow-pig-nursery	9	2 385	98	84	5
Farrowing 1	11	7 268	127	256	7
Farrowing 2	11	6 450	127	227	7
Total		32 758		1 153	34

Now, the cost of electricity was calculated using the m^3/min required for ventilation, and the number of days per season when it is necessary to provide a continuous ventilating rate in the swine building. Considering that to move 0.28 m^3/min requires 1 watt of energy, and that its price was 6 cents per kWh (March, 1987), the cost of ventilating is:

$$Vc = (\text{Number of days} \times m^3/\text{min} \times 24 \times \text{Cost per kWh})/280$$

The number of days required to provide the minimum winter ventilating rate continuously was taken from the Climatography of the United States No. 84, Grand Rapids, Michigan.

From these results it is possible to figure out that in the heated-hallway system the energy used to produce an adequate level of temperature (heating) and ventilation (electricity) is better used than in the conventional system. In fact, it produces a saving of around 11% of fuel to operate the furnace, and a saving of 15% of electricity energy to operate the fans continuously during the seasonal period.

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(Continued from page 79)

Simulation Model for Poultry Ventilation Rates and Supplemental Heat in Winter

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EuroTier '93 — International DLG Exhibition for Livestock and Poultry Production and Management

June 22-25, 1993
Hanover Fairgrounds
Germany

For a few years now there has been a growing trend towards professionalization in milk and beef production, comparable with the specialization in pig and poultry production.

Optimization of all production sequences by means of efficient technology, efficient deployment of inputs and modern management are thus the factors which determine the success of the meat, egg and poultry production sector.

EuroTier is the logical expansion of the proven and internationally successful Huhn & Schwein exhibition concept to include milk and beef produciton. Thus as a unique event in Europe, the complete international programme for pig, cattle and poultry production will be combined in Hanover for the first time in 1993.

Prospects for the exhibitors:
The combination of all production sectors together provides the outfitting industry and the input suppliers with an efficient exhibitionplatform for all fields of livestock production under a single roof every two years.

- As outfitter for all production areas you will reach your different target groups at a single event and can thus concentrate your forces optimally.
- As supplier for a special, specific production range you will profit from the attraction of this top event which brings together all experts and specialists from home and abroad to one location in Germany, in the heart of Europe.

EuroTier is the logical reply to the increasing number of exhibitions emerging worldwide. Concentration instead of inflation — to the benefit of the exhibitors and the visitors.

Compact livestock presentation in a modern environment: In the past, national and international breeding enterprises and associations have presented themselves purposefully and successfully at Huhn & Schwein. The livestock exhibits served above all as examples for the presentation of performance-relevant features.

This is to be the same for EuroTier and will also apply for presentations of breeding cattle for milk and/or meat production, geared to market requirements.

EuroProcessing for processors in the poultry sector: — an exhibition within the Exhibition — This self-contained part of EuroTier will take account of the special needs of the outfitters for processors of poultry meat and eggs. Closely connected with the production technology, inputs and breeding for poultry production in terms of exhibition space and programme, this sector will be specially highlighted and marketed worldwide with publicity measures geared to the specific target groups.

For further information contact:
Deutsche Landwirtschafts-Gesellschaft
Zimmerweg 16 W-6000 Frankfurt am Main 1
Phone (069) 71680

The Royal Show

July 6-9, 1992
National Agricultural Centre
Stoneleigh Park
Warwickshire CV8 2LZ
England

The National Agricultural Centre, campus of the Royal Agricultural Society of England, dedicated to the year-round transfer of agricultural technology, hosts the Royal International Agricultural Exhibition, the United Kingdom's world-class agricultural and agri-business event.

The Exhibition is dedicated to the promotion, communication and demonstration of biological and engineering science and technology, to the service of food production worldwide, in both crop and animal production systems — and the related issues facing each part of the food chain and the natural environment. It is a world market place for science-based products and services: finance and communication; intensive livestock systems; biotechnological livestock breeding; crop protection, plant nutrition and environmental issues.

More than that, the livestock section of the Exhibition, involving all the major domesticated breeds of farm animal, expresses all that is best in European animal improvements. With the participation of over 2,500 livestock exhibitors, over 1,500 trade exhibitors from the United Kingdom and overseas companies and areas dedicated to field demonstrations, the Royal International Agricultural Exhibition is at one and the same time a market place, a centre for information and an exercise in agricultural extension.

The new Gardening and Horticulture area will be a combination of trade exhibits, technical features and special displays, encompassing the Royal Show's renowned Flower Show. The intention is to develop an area which provides both a business forum and a showcase for a wide spectrum of trade and visitor alike. This will include for example, suppliers of hardy nursery stock, ornamental trees, garden centres, gardening and horticultural equipment. The audience interest profile ranges from the professional gardener/landscape architect/designer, through to the amateur (but very serious!) hobby gardener.

The Machinery Lines, centrally located and combined with demonstration areas, provide visitors with a major opportunity to see the widest range of equipment in the United Kingdom and enables prospective purchasers to assess clearly which equipment will suit their business.

Each year, over 26,000 international visitors from over 130 countries attend the Exhibition to examine technology, collect and disseminate information — and to do business, whether as individuals or as Ministerial-led delegations.

Agriculture and food is the world's most global business. Those involved, from policy-makers to practitioners, meet at the Royal International Agriculture Exhibition each year.
For further information contact;
Royal Agricultural Society of England
National Agricultural Centre
Stoneleigh Park
Warwickshire, England CV8 2LZ
Tel: International (44) 203 696969

France and IRRI Agree to New 5-year Joint Research Plan

Los Baños, Philippines — Scientists of France and the International Rice Research Institute (IRRI) will continue their successful collaboration in rice research for another 5 years.

This was jointly announced on 6 March at the conclusion of a France-IRRI research planning meeting by Dr. Klaus Lampe, IRRI Director General, and Mr. Henri Carsalade, Director General of the *Centre de Cooperation Internationale en Recherche Agronomique pour le Developpement* (CIRAD), who also spoke on behalf of the *Institut Francais de Recherche Scientifique pour le Developpement en Cooperation* (ORSTOM) and the *Institut National de la Recherche Agronomique* (INRA). All three institutions deal with agricultural research in the tropics.

"France has a long history of pioneering rice research in Africa and Indochina," Lampe said. "Their scientists have worked in rice in the tropics and sub-tropics since the beginning of the century."

"The France-IRRI collaboration will focus on varietal improvement, genetic resources, applications of biotechnology, agronomy, socio-economics, and rice-based farming systems," Carsalade said. "Asia will be the area of emphasis, but we will also collaborate in Africa."

Information will be shared between IRRI and the French institutions.

Carsalade headed the 7-member French delegation that came to IRRI 4-6 March to prepare the joint work plan. The French component of the collaborative research program will be carried out by CIRAD, ORSTOM, and INRA.

France and IRRI have cooperated in rice research activities since the late 1970's. Since 1978, 7 senior scientists and 2 junior scientists seconded to IRRI by French research agencies have contributed a total of 30 person-years of research activities. France is a major contributor to the IRRI core budget, and has provided major funds for the Institute's building renovation program.

Joint collaboration between IRRI and the three French research institutes was formalized in September 1986 by a Memorandum of Understanding. This was the third formal collaborative meeting held between France and IRRI. ■■

NEW PRODUCTS

The mission of the Committee to Encourage Technical Research is to show the advantages of the technical achievements of French and foreign manufacturers which are exhibited at the SIMA, SIMAVER, SIMAVIP, offering a character of novelty or original improvements which can be considered as progress in the field of agricultural mechanization.

No. 1 GOLD MEDAL at 63rd SIMA

Microwave Localization System for Agricultural Machines

by AGATE S.A.

This microwave localization system consists of one element installed on the machinery and a network of ground beacons.

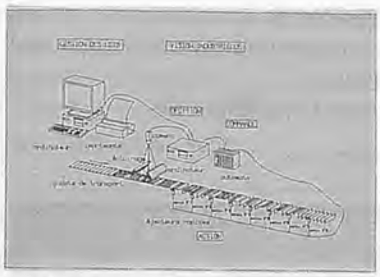
The element on the machinery consists of an aerial attached to a processing module which, together, make up the mobile. It transmits a modulated carrying frequency centred on 2442 GHz and processes a return signal sent by the beacons which, when active, transmits on 5786 GHz in their reserved time slots.

Reliant on the "AXYLE" sensor, these technologies have been adapted to be of initial use in localization complementary to the laser plane to simplify operations preceding drainage works and enhances the reliability and the quality of drain installation. Later the system may be able to offer substantial economies for the introduction of plant food and health products as soon as precise adjustment of the supply can be made according to the topographical needs.

No. 2 GOLD MEDAL

Automatic Asparagus Grader Using Industrial Monitoring

by CIME AGRO S.A.



This new grading system is offered to producer groups and co-operatives. It feeds crates and loads them for washing by immersion, positions the asparagus (controlled manually), cuts and rinses-with movement handled by a double belt conveyor.

A system of industrial monitoring, which measures and grades the asparagus, consists of a matrix camera, artificial lighting, an image analyser, a robot and processing controller.

The turion is measured by diameter and length, the grading following their morphology (straightness, single stalk, non-woody, uncracked); the end bud (pointed, in flower or broken); the standard colour criteria (white, green or violet) and non-standard (rust). According to the information received on these criteria, the robot directs the asparagus towards one of fifteen relevant exists, before they are packed and paletted.

No. 3 GOLD MEDAL

Reaper and Baler with Extra Wide Disks

by KUHN S.A.

Conceived in response to demand from contractors and CUMA, the 5 m wide "ALTERNA 500" reaper and baler offers considerable manoeuvrability, at work and in transport, as well as the opportunity of opting for a return cut on the right or the left of the tractor.

The position of the shaft is automatically checked at the time of the half turn; the machine adjusts itself to one side or the other of the tractor without the need for intervention from the driver.

The cutting mechanism, with two bars of cutting disks rigidly linked together, is laid out with each carrying structure supporting a baler. Movement is effected by a transmission in the shaft as far as a central casing installed at the level of the joiont connecting the shaft to the chassis. Movement is then transmitted to the cutting mechanism.

The suspension, in the form of a stretched parallelogram, is another important innovation: allowing greater concentration on the points of connection with the chassis. Combined with a centralised device for fine tuning, it adjusts perfectly to the terrain. Its "triangulation" structure gives great rigidity and excellent security to the harvesting mechanism in the event of it hitting objects at high speed.

No. 1 GOLD MEDAL at 9th SIMAVIP

Henhouse Climate Control Plant
by TUFFIGO S.A.

This control plant provides synchronised and co-ordinated control over all environmental elements within the building.

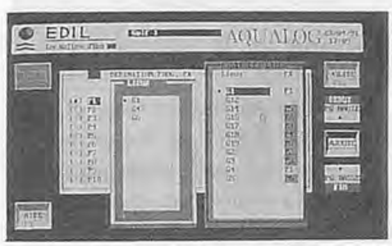
Ventilation and heating react according to probes measuring temperature, humidity, barometric pressure or, if necessary, according to measurements from a weather station.

The reactions are on four principal levels: a reference point (above which ventilation becomes more forceful, below which it works on a cyclical basis); a range (degrees above the reference points to obtain the maximum of ventilation); a security point against cold (degrees below the reference point below which ventilation ceases); and a humidity reference point (humidity percentage above which heating and ventilation becomes more forceful).

Automatic calculation of the ventilation minimum, based on a parametric curve, allows true ventilation variance according to the needs of the animals, giving them greater comfort. All parameters, also accessible in France through Minitel, can be varied according to the age and weight of the animals.

No. 1 GOLD MEDAL at 14th SIMAVER

Computerized Watering Control System
by SADIMATO S.A.



The "AQUALOG" is a dynamic control and guiding device for irrigation systems which takes into account local weather conditions. Its original technological features lie in the type of remote control and bidirectional multiplex means of communication between the central processing unit, the sensors and the multi-encoders.

The system is designed for use in parks, golf courses, race courses and other open spaces. It offers a centralized technical control, providing,

- control of the water supply, capable of reducing water consumption,
- a rational use of sprinklers,
- safety devices protecting the piping and the pumping plant from the danger of overload,
- remote monitoring of the solenoid valves and remote metering of the data transmitted by the sensors connected to the multi-encoders.

Designed for rapid handling by users, the spray rate is calculated prior to each watering cycle, in accordance with the watering chart determined by the measurements, the evapotranspiration, the sprinkler output and the cultivation requirements for each plant site. Pumping is optimised according to the range uses.

By means of a recording, a continuous remote diagnostic system monitors the operation of the solenoids valves, the guiding lines and the pump, by means of the sensors linked to the multi-encoders (flow-rate, pressure, temperature, etc.).

No. 2 GOLD MEDAL

Universal Chain Saw
by A STIHL S.A.R.L.

This lightweight (7.3kg) "066" 5kW chain saw is suitable for cutting thick and hard woods, as well as trimming branches. It incorporates several innovations, in particular an LED display for easy adjustment of the motor speed, even on site.

The compensated carburettor keeps the air-fuel mixture constant, regardless of any clogging of the air filter, which adds considerably to the reliability of the saw.

Finally, the digital elecrtonic ignition ensures starting without any danger of kick-back and, for the first time, provides an automatic ignition advance adjustment (adjustment by the stroke). ■■

BOOK REVIEW

Elements of Farm Machinery

(India)

by A.C. Srivastava

Use of agricultural machinery has been widely accepted by farmers around the world and specially in developing countries. Very often farm machinery suffer major and miner breakdown while working in a typical and arduous farm environment. These irregularities are put in order through experience and through basic understanding. (Such tit-bits of information are insufficiently found in available books and in the literature.) Efforts have been thus made to synthesize such information in a form of a handy book.

This book has been divided in three parts: A. operation and maintenance, B. basic theory and mechanics and, C. examples and exercises. While the first part elaborates the information required by an operator, the second part provides some basic understanding of the machine and its mechanisms. Part C contains examples and exercises specially for learning and teaching the subject. The book, in its present form, will be useful to students, teachers and for persons concerned with the farm equipment.

Size: 22.5 × 14.5 cm, pp.337, soft cover

Published by Oxford & IBH Publishing Co. Pvt. Ltd., 66 Janpath New Delhi 110001, India

The Indian Journal of Agricultural Engineering — A Quartery Publication

(India)

The Indian Council of Agricultural Research is bringing out. The Indian Journal of Agricultural Engineering, priced at US$5, UK Pounds 2.50.

The journal would include articles on 'Farm implements and machinery, energy and farm power, post-harvest engineering and technology including dairy engineering; agricultural structures and environment control; soil and water conservation, irrigation and drainage engineering'.

The articles will be subjected to technical scrutiny by two specialists and only those meeting high standards will be published.

The technical information provided in the journal would be of much interest to all those concerned with the discipline of Agricultural Engineering.

Published by Indian Council of Agricultural Research
Krishi Anusandhan Bhavan
Pusa, New Delhi, India

Progress in Agricultural Physics and Engineering

(U.K.)

Edited by John Matthews

The physical sciences and engineering play an important part in the advance and activities of agriculture and related industries and in the preservation and improvement of rural and amenity environments. This book provides an authoritative account of new developments in these disciplines as applied to such industries.

Chapters have been commissioned on topics perceived to have made important recent advances and these are reviewed by authors of international repute. The book will therefore have immediate value for research workers, lecturers and professionals in agricultural engineering and applied aspects of soil science, horticulture, food science and other disciplines.

Contents include:

- An analysis of research priorities in agricultural physics and engineering *J Matthews*
- The mechanics of soil machine interaction *R D Wismer (Deere & Co., Illinois) and D R Freitag (Tennessee, USA)*
- Tractor ride dynamics *H Gohlich (Berlin, Germany)*
- Stability of agricultural machines on slopes *A Hunter (Edinburgh, UK)*
- The principles of robotics in agriculture and horticulture *F Sevila & P Baylou (France)*
- Image analysis in biological systems *J Marchant (Silsoe, UK)*
- Climate modelling and control in greenhouses *B Bailey (Silsoe, UK)*
- Heat and mass transfer in the drying and cooling of crops *J L Woods (University of Newcastle upon Tyne, UK)*
- Damage mechanisms in the handling of fruit *M Ruiz Altisent (Universidad Politecnica Madrid, Spain)*
- The physics and engineering of the extraction of protein from green crops *R Reznicek (Czechoslovakia)*
- Principles of abattoir design to improve animal welfare *T Grandin (Colorado, USA)*
- Biological waste treatment *W Baader (FRG)*

350 pages, Hardback.

Price including postage: £49.95 (US$95.00 Americas only).

Published by C.A.B. International
Wallingford, Oxon OX10 8DE, U.K.

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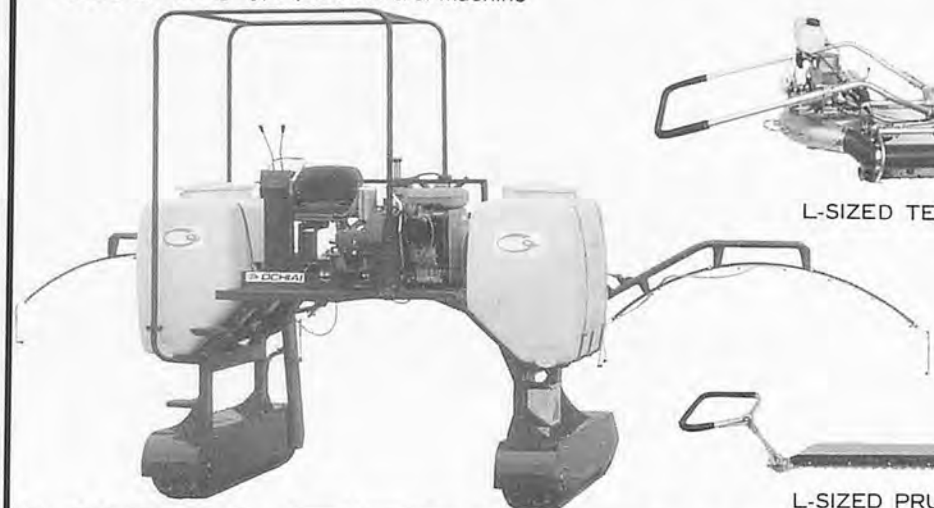
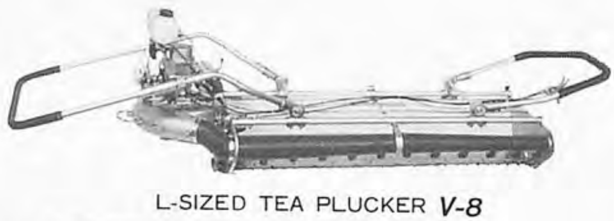
(Vol. 22 No. 1, Winter 1991 ~)

OCHIAIi is the top-ranking tea-leaf piker manufacturer in Japan. OCHIAI's products are used in tea-producing areas worldwide.

OMS-2 Riding type pest control machine



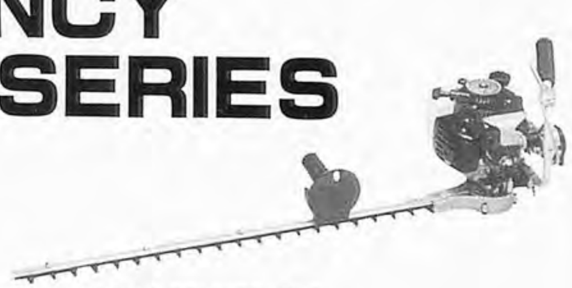


L-SIZED TEA PLUCKER ***V-8***

L-SIZED PRUNER ***R-8***

HIGH-EFFICIENCY RIDING TYPE SERIES

OM-25 Full-width tea picker



ENGINE PRUNER ***E-6***

GUIDE TO OCHIAI

- Succeeded in devising Japan's first automatic tea-leaf picker in 1959.
- Received the Director of the Board of Scientific Technology Award in 1967.
- During the intervening period (1959-1967) obtained a number of patents, as well as receiving a variety of awards and prizes in the domain of science and technology.
- The top-ranking tea-leaf picker and tea-tree trimmer producer, holding 60% of the shares in the same line of business in Japan, surpassing the other manufacturers in sales and product, and leading the related business worlds in its expansion and development.

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