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EDITORIAL

CIGR World Congress held in Milano from August 29 to September 1 was very successful with about one thousand attendance. The meeting obtained excellent results by the efforts of Dr. Pellizzi, a president of CIGR, and the persons concerned. From ASAE, which decided to rejoin CIGR in August, Dr. Janssen, a president, Dr. Stout, a vice president and Mr. Castenson, a vice president attended the meeting. Also with the attendance of Dr. Singh, a president of Asian Association of Agricultural Engineering (AAAE), of the representatives from Southeast African Society of Agricultural Engineers and Brasilian Society of Agricultural Engineers, it became a really international meeting.

Under the existing severe circumstances surrounding agriculture, the budget for agricultural research got to be reduced. On the other hand population problem is getting worse especially in rural area in developing countries. In view of these realities, it is most expected to raise agricultural productivity, promoting its mechanization, in developing countries. In order to realize it with limited budget and staff, we need to unite our efforts at international level. An effective international cooperation system over nations will be essential to the solution of many existing problems. In this context we expect that CIGR should take the leadership in building up worldwide network for the cooperation. The meeting elected Dr. Berge of Agricultural University of Norway as a new president and Dr. Kitani of Tokyo University in Japan as a president-elect for the next year.

Population increase and the demand for food in Asian developing countries will be the world most serious in the future. There were many attendance from China. Asian agricultural engineers should have linkage in their research activities under close cooperative relationship between CIGR and AAAE. The meeting also discussed the new project to connect members via electronic mail, which will enable us to do more speedy, sure and cost-saving communication. I would appreciate the assistance of AMA readers in putting this project into operation. At first we need to make worldwide address list for electronic mail. Electronic mail, including FAX, will have a great power to change a state of communication completely in the future.

Though many difficulties lies in the way to promote agricultural mechanization in developing countries, we should unite our efforts for the attainment of our objective. AMA is eager to make contribution for the solution of the problems. The support from readers will be appreciated.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
October, 1994

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Norms of Draft Power Sources under Agricultural Conditions

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Abstract

Area controlling capacity and norms for bullock power and tractor power sources are determined for paddy-wheat, maize-wheat and sugarcane plant-sugarcane ratoon-wheat crop rotations dominant in north India. It was found that a pair of bullocks with indigenous implements can control 1.5 ha area and a pair of bullocks with improved implements can control 2.0 ha area for the best production. For a 20-bhp tractor 1.0 hp per ha and for 35 bhp-50 bhp tractors 1.25 hp per ha may be taken as the optimum power for meeting the best production norms.

Introduction

The major draft power sources used in Indian agriculture are bullocks and tractors although some other animals like buffaloes and camels are also used. The use of power tillers is on limited scale in some areas. **Table 1** shows the distribution of major draft power in India. On the basis of 1991 estimates, the availability of power on Indian farms is about 0.55 hp/ha of cultivated area. The contribution of draft animal is about 52% and the rest comes from tractors and power tillers.

Table 1. Distribution of Major Draft Power in Indian Agriculture

Draft Power Source	1951	1972	1982	1989	1991 (estimated)
Draft animals	—	66×10^6	80×10^6	83×10^6	83×10^6
Tractors	8 354	148 200	518 500	950 000	1 100 000
Power tillers	N.C.	17 200	29 700	35 000	50 000

SOURCE: Report of the sub-group on agricultural implements and machinery for formulation of the Eighth Five Year Plan (1990-95), Govt. of India, Ministry of Agriculture, Department of Agriculture and Cooperation.

Earlier studies have shown that the use of adequate power results in timely operations, increased cropping intensity and better quality of field work in terms of crop yield. However, excess power in a developing country like India may not only divert scarce capital resources but also result in wastage of fuel and fodder energy without effectively increasing the production. It is, therefore, desirable that a norm is determined for optimum draft power on Indian farms which may serve as a guideline for selecting power source for the farmers, planners and policy makers.

Review of Literature

Johnson (1964) reported that most tropical areas grow only one crop per year although two or three crops usually were possible. The role of energy to harvest rapidly, process, plough, replant and irrigate the second or third crops limited the number of days of production per year.

Giles (1967) found that the average aggregate yield of major crops per hectare is a function of horse power available /ha of cultivated areas. He was suggested that in order to obtain yield of 2-3 t/ha, the power unit ranging from 0.50 to 1.00 hp/ha would be required.

The demand for energy by a farmer is a function of the crops raised and its acreage, type of soil, level of rainfall and the technology used (Billings and Singh, 1969). Singh and Chancellor (1974) studied the relations between farm mechanization and crop yield for a farming district in north India and observed that there is little evidence to show that significant increases in crop yields can be effected by mere substitution of mechanical power for animal power if the timeliness or quality of work done is not changed.

In analyzing the level of tractor power utilization in north India, Singh and Singh (1975) found that the maximum use of tractor is for wheat sowing in the month of November. Yadav (1982) studied the energy requirement in paddy production system and concluded that up to 3 ha of landholding bullock power with improved implements, for 4-10 ha a power tiller and for land size above 10 ha, a 35 hp tractor with matching implement is the economically viable power source.

Banga and Gupta (1983), in surveying tractor and non-tractor farms observed that for wheat cultivation preparatory tillage consumes more than half of the total energy on tractor owning farms while 3/4 of bullock energy on non-tractor farms was used for preparatory tillage.

Singh (1984) studied the power availability in selected southeast Asian countries and reported that in Indonesia, Malaysia, Philippines and Thailand, the draft power available /ha of cultivated land was 0.25 kW, 0.20 kW, 0.40 kW and 0.60 kW in 1978 of which the contribution from power tillers and tractors were 5, 65, 55 and 72%, respectively.

Jain (1985) recommended stepping up the power input to a level of 1 hp/ha for Indian agriculture, from a level of 0.6 hp/ha available mostly from 66 million bullocks, 7.5 million pump sets and 0.6 million tractors on a total of about 145 million ha of cultivated area.

Yadav and Survanto (1990) reported that the available draft power for agriculture is 0.48 hp/ha in India and 0.24 hp/ha in Indonesia.

On the basis of data collected in 1989 from different regions of the Republic of Korea, Park (1990) reported that 53% of the total households owned power tillers and 2% tractors. The farm households had an average of 1.19 ha cultivated land.

The above studies indicate that the availability of greater power is essential for increasing crop yields; that draft power available in Indian agriculture is low; and draft power of 1 hp/ha of cultivated area is suggested as the desired level. It is, therefore, desirable that these norms for draft power be observed by farmers.

Materials and Methods

In determining the norms of power requirements from different power sources in north India, observations were made for time used in different farm operations for the production of major crops like paddy, maize, wheat, sugarcane plant and sugarcane ratooon in *tarai* region of Uttar Pradesh. These crops are grown under paddy-wheat, maize-wheat and sugarcane plant-sugarcane ratoon-wheat crop rotations. These rotations cover almost 80% of cultivated area in north India. The observations were taken over a period of 3 years. The power sources used in the study were: (i) bullock power with indigenous implements; (ii) bullock power with improved implements; (iii) 20 bhp tractor; and (iv) 35 bhp tractor with matching implements.

The following assumptions guided the study:

1. The optimum period during which the intensity of use of a power source is maximum is taken as the base in calculating the area controlled by a particular power source.
2. On the basis of earlier observations taken under different agro-climatic conditions, the seedbed preparation and sowing operations consume maximum energy for crop production.
3. The optimum periods required for sowing/planting of maize, paddy, wheat and sugarcane are as follows:
   Maize: June 10 to June 25 (15 days)
   Paddy: June 15 to July 15 (30 days)
   Wheat: November 1 to November 30 (30 days)
   Sugarcane (Planted):
      (i) October 1 to October 15 (15 days for autumn planting)
      (ii) February 1st week to March 15 (40 days for summer planting)
4. The availability of land is unrestricted, i.e., the land is available and the power source is not expected to remain idle for want of land during the optimum period.
5. The source of power is mainly used for field operations from seedbed preparation to sowing/planting of crops during the critical period in wheat also.
6. All the operations from tillage to sowing/planting are accomplished on time as demanded by soil and crop requirements through a given source of power.
7. The time required in carrying out the individual as well as total operations is the average time for different crops.
8. In order to achieve the sowing/planting of a crop within the optimum period it is necessary that the tillage operations leading to seedbed preparation are started in advance. It is assumed that an average of 7 days would be available for preparatory tillage in addition to optimum time of sowing/planting.
9. A power source is assumed to work 8 h per shift per day. The animal (bullock) source of power is assumed to operate one shift per day only even during the peak periods of requirements. However, during this period the mechanical

sources of power are assumed to work in two shifts of 8 h each.

10. The time efficiency of power source is taken as 80%. This accounts for the time lost in to-and-fro movements of the power source from shed to the field and weather factor, time taken for transport of seed, fertilizer and other works.
11. Keeping into account the breakdown of mechanical power sources and implements, the actual availability of mechanical sources for field operations during peak periods is assumed to be 80% on the average.

In order to cmplete the operations of seedbed preparation and sowing during the periods specified above the total number of days available for operations of maize, paddy and wheat crops are 22, 37 and 37 days, respectively. For autumn and spring planting of sugarcane, 22 and 47 days would be available.

Effective Operational Time of Power Sources

The actual time for operations of seedbed preparation and sowing for a crop with different power sources may be computed as:

$$T_a = N \times H \times \eta_t \times \eta_a \times n$$

where,

T_a = actual available time of power source in hours during critical period of seedbed preparation and seeding operations.

N = number of shift of operation per day.

H = hours per shift per day.

n = number of critical (optimum) days in the season during which the operations are to be completed for a crop.

η_t = time efficiency of power sources.

η_a = availability of power source and equipment system during the critical period.

On the basis of experimental field observations the time of power source required for seedbed preparation and sowing per hectare of the crops was determined.

Area Controlling Capacity of Power Source and Norms for Power

The area controlled by a power source is calculated as follows:

Area controlling capacity

$$(\text{ha}) \times (\text{ACC}) = \frac{T_a}{T_h}$$

where,

T_a = actual available time of a power source system in hours during critical period of seedbed preparation and seeding of a crop.

T_h = time taken in hours per hectare for seedbed preparation and seeding of the same crop with the same power source system.

The values of ACC varies for different crops for the same power source system due to different seedbed conditions and effect of previous crop reduces.

For the purpose of deciding the norm for the power source in term of power needed per hectare the maximum value is taken as the norm.

Results and Disucssions

The average of actual field experiments conducted with two bullock power systems and two tractor systems for paddy, maize, sugarcane and wheat crops are shown in **Tables 2-4**. For wheat crop the results are given for paddy-wheat, maize-wheat and sugarcane plant-sugarcane ratoon-wheat crop rotation.

Bullock Power Source System

A pair of bullocks was used with indigenous implements in one system and with improved implements in the second system. The details of various seedbed preparation and seeding operations for paddy, maize and sugarcane (planted) crops are given in **Table 2**. In **Table 3** the details are given in respect of wheat crop grown under different cropping rotations.

The tables show that in both power systems, wheat under paddy-wheat crop rotation takes maximum time of a pair of bullocks for seedbed and seeding operation. In the case of bullocks with indigenous implements a maximum of 194.08 h of a pair of bullocks are needed per hectare of wheat crop under R_1 crop rotation. Similarly, a maximum of 142.16 h/ha are needed for bullocks with improved implements. As mentioned under various assumptions one pair of bullocks is used for one shift of 8 h/day, time availability of bullock power is 100%, break down of implements is almost nil and 37 days optimum period is available for seedbed and seeding operations for wheat sowing after paddy crop.

The available time

$$= 37 \times 8\text{ h} = 296\text{ h}$$

Hence,

Area controlling capacity (A.C.C.): for bullocks with indigenous implements

$$= \frac{296}{194.08} = 1.53\text{ ha}$$

Area controlling capacity (A.C.C.): for bullocks with improved implements

$$= \frac{296}{142.16} = 2.07\text{ ha}$$

These results indicate that for paddy-wheat crop rotation and

Table 2. Time Taken for Seedbed Preparation and Seeding of Paddy, Maize and Sugarcane Crops with Different Power Source Systems

Crop	Operations	Bullocks with indigenous implements		Bullocks with improved implements		20 bhp tractor		35 bhp tractor	
		No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)
Paddy	Ploughing	2	71.71	2	71.69	—	—	—	—
	Wet land levelling	3	17.59	3	14.94	—	—	—	—
	Harrowing & Planking	—	—	—	—	2	7.52	2	6.36
	Puddling	2	60.05	2	44.89	2	8.40	2	5.20
	Total		149.35		131.52		15.92		11.56
Maize	Ploughing	2	56.15	1	22.50	—	—	—	—
	Harrowing	—	—	2	28.72	2	6.52	2	4.11
	Planking	3	15.61	2	9.48	2	1.46	2	1.30
	Sowing	1	14.25	1	8.90	1	1.97	1	1.34
	Total		86.01		69.60		9.95		6.75
Sugarcane Plant	Ploughing	5	119.73	2	53.98	—	—	—	—
	Harrowing	—	—	2	30.25	4	12.15	4	8.21
	Planking	5	23.55	4	19.34	4	2.38	4	2.26
	Sowing	1	27.08	1	24.30	1	2.20	1	1.31
	Total		170.36		127.87		16.73		11.78

*Time - Tractor - hours/ha or bullock - hours/ha.

Table 3. Time Taken for Seedbed Preparation and Seeding of Wheat Crop under Various Crop Rotations and with Different Bullock Power Systems

Operations	Bullocks with indigenous implements						Bullocks with improved implements					
	R_1		R_2		R_3		R_1		R_2		R_3	
	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)
Ploughing	4	128.27	3	66.52	4	96.15	2	64.97	1	20.63	2	52.12
Harrowing	—	—	—	—	—	—	2	46.12	3	41.17	3	38.00
Planking	8	45.74	4	23.47	4	30.30	4	23.34	3	19.18	3	22.68
Sowing	1	20.07	1	23.29	1	21.87	1	7.73	1	11.13	1	13.08
Total		194.08		113.28		148.32		142.16		92.11		125.88

*Time - Pair of bullock hours/ha.
R_1 - Paddy-wheat crop rotation. R_2 - Maize-wheat crop rotation. R_3 - Sugarcane ratoon crop rotation wheat.

Table 4. Time Taken for Seedbed Preparation and Seeding of Wheat Crop under Various Crop Rotations and with Different Tractors

Operations	20 bhp tractor						35 bhp tractor					
	R_1		R_2		R_3		R_1		R_2		R_3	
	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)	No. of operation	Time (hr)
Ploughing (one way)	—	—	—	—	1	3.38	—	—	—	—	1	2.80
Harrowing	4	11.22	3	7.08	3	9.52	4	8.44	3	5.32	3	6.40
Cultipacking	2	3.42	—	—	—	—	2	1.75	—	—	—	—
Planking	3	1.81	3	2.18	3	2.42	3	1.70	3	2.26	3	2.25
Sowing	1	2.03	1	1.84	1	1.82	1	1.57	1	1.27	1	1.36
Ridge making	1	1.12	1	1.12	1	1.12	1	0.58	1	0.58	1	0.58
Total		19.60		12.22		18.26		14.04		9.43		13.39

R_1 - Paddy-wheat crop rotation. R_2 - Maize-wheat crop rotation. R_3 - Sugarcane-wheat crop rotation.

wheat production system 2 ha landholding can be effectively controlled by a pair of bullocks with improved implements. Yadav (1982) recommended 3-ha area for such a power system in paddy production system. Since the total time needed for paddy, seedbed preparation is less than for wheat, the area controlling capacity in wheat crop would be less than for paddy.

Tractor Power System

The time taken under various operations for seedbed and seeding of paddy-maize and sugarcane plant crops for 20 bhp and 35 bhp tractor with matching implements are given in **Table 2**. The same results for wheat crop under 3 crop-rotations and for 20 bhp and 35 bhp tractors with matching implements are given in **Table 4**. These figures show that maximum tractor hours per hectare are needed in the case of wheat crop under paddy-wheat crop rotations for both tractors.

On the basis of assumptions made earlier and the results given in **Table 4**, the power requirement norms are as follows:

Item	20 bhp tractor	35 bhp tractor
Tractor hour needed per hectare	19.60	14.04
Tractor hour available for field work in the season	378.90	378.90
Area controlling capacity during the season (ha)	19.33	26.98
Tractor power needed (bhp/ha)	1.03	1.29

The norms given in the above table hold true when paddy is hand-harvested. However, when paddy is harvested by combines, two additional operations of harrowing are usually needed for seedbed preparation. Under such a condition the area controlling capacity of tractors will decrease and norms for tractor power needed will increase. On the other hand, where soil is sandy, the number of tillage operations needed will be less in order to prepare the seedbed. This will result in better area controlling capacity of tractors and, consequently less bhp norm per hectare will be needed.

The results also show that a 20 bhp tractor is relatively better utilized on different operations as compared to 35 bhp or higher bhp tractors is that for the same operation per bhp output of a 20 bhp tractor, is more than per bhp output of 35 or higher bhp tractor. In a survey conducted in Tarai region, it has been observed that on the average, the farmers in this area have 35 bhp tractors over 6 ha land. Assuming some custom work also, the maximum area per tractor of 35 bhp may be taken as 12 ha. It means the actual availability of power is 3 hp/ha.

Conclusions

On the basis of the above studies the following conclusions are made:

1. Seedbed preparation in wheat crop under paddy-wheat crop relation takes maximum time of all draft power sources.
2. For obtaining maximum yields of wheat period available for seedbed preparation is only about 37 days.
3. A pair of bullocks with indigenous implements can control only 1.5 ha area. Whereas a pair of bullocks with improved implements can control 2.0 ha area effectively.
4. For tractors in the range of 18-29 bhp 1.0 bhp/ha may be taken as the norm of power.
5. For tractors in the range of 30-50 bhp 1.25 bhp/ha may be taken as the norm of power for achieving optimum production.
6. Should paddy harvesting be done by combine harvesters such that paddy stubbles are left in the plot, the norm for tractor power requirement will increase by 25%.

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Measuring the Drawbar Performance of Animals and Small Tractors

(I) Development of a Loading Device

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Abstract

A review, based on the characteristics of animals and tractors, is made of the principles of testing the drawbar performance of these power sources.

A device which was developed for generating and measuring a draught load necessary in measuring this performance is described. This was implemented in two forms - a towed vehicle for animals and tractors working on firm soils, and a pull-out rig suitable for generating a horizontal draught for tractors working on soft soils.

Introduction

With the increasing use of animals and small tractors as power sources in the mechanization of agriculture, there is need for training and research in their development and use. Like most power sources, their performance cannot be accurately predicted and it is, therefore, necessary to measure it under various conditions. The management of animals and tractors will, of course, be different due to their different nature and characteristics. However, the measurement of their performance has much in common and, in some circumstances, similar loading device which is suitable for the evaluation of both.

The development of this device and its implementation on two different rigs for measuring the performance of tractors on soft soils and of animals and tractors on firm soils is described. In doing so, it is convenient to review the characteristics of animals and tractors and to note their differences so that the testing regimes appropriate to their respective characteristics can be seen. This is shown in **Table 1**.

If the performance of animals and tractors, which is influenced and limited by their interaction with the soil, is to be understood, it should be measured in terms of the fundamental parameters such as drawbar pull, travel speed, and drawbar power at various load levels. However, performance data, specified in these terms, is not available because suitable equipment for generating and measuring the drawbar load, particularly under soft soil conditions, is not available.

A further factor in testing power sources is the need to separate the effect of the direction of the load. In formal tractor testing, this has traditionally been done by using a device that generates the horizontal draught. A vertical component is then simulated by adding static weights to the tractor and repeating the tests.

In terms of animals, these effects are usually confounded and the result is, in effect, the testing of an animal and implement system (Lawrence and Pearson, 1985). However, Lawrence and Stibbards (1990) conducted experiments where these effects were separated and this allows a more fundamental analysis of a particular class of drawbar operations (Macmillan, 1992).

Existing Test Methods

The testing regime required for animals is not the same as for tractors because, as noted in **Table 1**, the period of work is a significant factor for animals. There are also other environmental and physiological factors that do not have analogues, or are not significant, in the testing of tractors.

The use of an agricultural oper-

Table 1. Comparison of Characteristics of Tractors and Animals as Power Sources

Tractors	Animals
A tractor is essentially an engine and associated transmission driving two or more wheels. It, therefore, has the characteristics of many such mechanisms:	An animal is quite different from a mechanical system such as a tractor and, hence its performance must be measured under different testing arrangements.
(a) Travel speed is the fundamental parameter for the tractor; it essentially is set by the engine speed and the gear ratio chosen by the operator. It will, however, vary somewhat with draught due to wheel slip.	(a) Speed is the fundamental parameter for the animal and is essentially constant for one type of gait (e.g., walking). It will, however, vary somewhat with the draught load.
(b) Its performance, in any given circumstances, is essentially constant, i.e., it does not vary with time due to tiring (as for an animal) or significantly due to wear. Hence measurement can be made over a short period of time; it can be assumed that the tractor could go on operating in that way indefinitely.	(b) Its performance will vary with time as the animal tires and becomes hungry. Hence it is necessary to test the animal in a controlled way for a long period of time, so that the effect of tiring is included in the performance. It will also vary with the extent of urging (e.g., shouting or even beating); if resorted to, its effect would be difficult to measure.
(c) Its performance is determined and limited by the capacity of: (i) the engine; (ii) the transmission; (iii) the wheels or tracks; and by external factors such as the strength of the soil on which it is operating.	(c) Its performance will be determined and limited by internal factors such as: (i) the strength of the animal, hence (ii) size (weight,) (iii) feeding, and by external factors such as: (i) the surface on which it is working, (ii) temperature, humidity, etc.
(d) Its performance may be measured by and represented in terms of fundamental parameters of mechanics such as force, speed, torque, power, fuel consumption, etc. It is not necessary to specify an implement or an operation being undertaken.	(d) Its performance may be measured by and represented in terms of fundamental parameters of mechanics such as force, speed, power, and physiological parameters, such as body temperature, heart rate, air consumption, etc. It is not necessary to specify an implement or an operation being undertaken.
(e) It is assumed that its capacity is not limited by the malfunction of internal mechanical systems such as slipping of the clutchor breakage of transmission components.	(e) Its performance is not mechanically determined and may vary from time to time according to various physiological changes.

ation (e.g., tillage), as discussed below, is a common method of generating a draught load for animal studies. Other workers have developed loading systems for controlled testing of animals on firm surfaces using suspended weights (Gupta, 1991) and friction drums (Gupta, 1992). Alternative systems use sledges (Bamualim et al., 1987) or loaded carts (Bakrie et al., 1987).

The use by Lawrence (1987) of a test track with a puddled soil and a controlled load is a convenient but fixed and somewhat expensive way of combining the best features of both field and controlled experimentation.

Tractors

With the increasing use of tractors for wet-land rice cultivation, especially in Asian countries, there is a need to develop an understanding of how to optimize their field performance when working on soft soils. However, there is little or no drawbar performance data on tractors working under such conditions. For example, the Test Code and Procedures for Farm Machinery established by the Regional Network for Agricultural Machinery (RNAM) (Anon 1983) does not include a drawbar performance test for tractors.

Performance data are obtained from axle performance tests under laboratory conditions by the Agricultural Machinery Testing and Evaluation Centre (AMTEC) (Anon 1992) and, while these are useful for showing the engine/transmission performance, they do not provide a basis for understanding the performance characteristics of tractors in field operation under various drawbar load conditions.

Field performance data such as field capacity in ha/h are also measured, but these are related to the combined performance of the tractor and implement together; it is impossible to separate the two components to derive the performance of the tractor alone. In addition, the single value of fuel consumption has a limited usefulness, in that it does not reflect the range of fuel efficiency at which the tractor may operate.

Implement-based System

An agricultural implement such as a plough may be used for generating a load during testing. Here, a force cell is introduced into the draught linkage and some method of measuring time and distance are included (Lawrence and Pearson, 1985; Gee-Clough et al., undated; Angod, 1985). This is an uncontrolled but convenient way of studying power units working in the field. However, without careful control and measurement of the experimental conditions, such work may reveal more about the implement and its operation than about the unit.

Further, this method is not particularly suitable for testing the power unit alone, for the following reasons:

- The implement does not apply a horizontal load; hence the vertical component is not known, nor is it likely to be constant.
- The range of load that can be generated is limited. Variation of the draught, which, for example, can be made by varying the implement depth, may be of such a magnitude that the required range of load for testing purposes cannot be achieved. With a small implement, it

may be possible to provide the required minimum draught, but the maximum draught will not reach the maximum capacity of the power source. On the other hand, a bigger implement may be capable of covering the maximum draught, but not the minimum.

- The control of the draught at a constant value is difficult. The draught in this system is determined by the implement depth as well as the specific draught of the implement/soil. Under field conditions, it is frequently difficult to maintain a uniform depth and the specific draught within a test area will not usually be constant. Hence, without relatively complex instrumentation, the fluctuating load makes data observation difficult; Angod (1985).

The work reported here was, therefore, directed towards the development and evaluation of a more suitable device which generates an adequate load to fullly explore the drawbar performance of animals and small tractors operating on firm soil and of small tractors operating on soft soil Pudjiono (1988).

Test System

Requirements

The development of the loading device for these two applications was based on the following general requirements:

- Generate a mobile draught load up to the maximum capacity of the source;
- Provide a minimum draught which is a small proportion of the maximum, e.g., not more than 10%;
- Allow precise adjustment of the draught, either in finite steps or in a continuously varying manner;
- Provide a constant draught at any setting, irrespective of minor speed variation; and
- Allow measurement of the draught.

Energy Absorption

Loading devices of this type require an energy absorption system to absorb mechanical energy, usually in the form of rotary motion, and dissipate it in the form of heat. The question which arises is 'what type of energy absorbing system is most suitable, economic, and will provide a realistic load for testing animals and small tractors?'. Macmillan (1985) reviewed the various types of energy absorbing devices (hydrodynamic, hydrostatic, aerodynamic, electric and mechanical friction) in relation to draught animal research and classified them on the basis of their speed characteristics, *viz.* high and low speed devices.

Animals and tractors in drawbar work operate at relatively low travel speeds, and hence they will produce low rotational speeds with any loading device. A low speed mechanical or hydrostatic device is, therefore, likely to be most suitable in any low speed rotary absorption system used in such testing.

In general, however, mechanical friction devices are more suitable than hydrostatic ones for the following reasons:

- They are simpler in construction and cheaper;
- The torque generated is insensitive to minor speed variation; this insensitivity ensures the stability of load generated by the device; and
- They provide a finite torque at zero speed, a characteristic which simulates an agricultural implement that generates a finite draught at zero speed.

In order to best satisfy the requirements for the loading device, a disc brake was chosen as the energy absorbing device because it has the following characteristics:

- Heat dissipation is good;
- It does not have a self-generating action as do some band brakes; and
- The torque generated is insensitive to the variation of brake conditions such as temperature and rotational speed.

Force Measurement

In using a conventional load vehicle, it is common to measure the drawbar load by attaching a force cell between the power source and the vehicle. However, in using the present device, it is convenient, for the following reasons, to infer the draught from a reaction force on the arm that carries the brake pads:

- The draught can be controlled and any minor adjustments can be made at the device;
- The use of a force cell attached to the power source requires the attention of the operator, or of a third person to read the record the values; and
- The person who sets the draught is also able to observe and record it.

A small hydraulic force cell, with 38.1 mm cylinder bore and associated pressure gauge, was fitted to the device as part of a programme of evaluating low-cost instrumentation. However, a force-cell of any type could be fitted if desired.

Control of Load

An actuator is required in the mechanism of the disc brake to apply sufficient clamping force on the brake pads to generate the required tangential braking force. Various ways might be used to achieve this clamping force:

- Gravity weights: here the action is force-controlled (which is ideal), but is subject to bouncing under variable surface conditions.

- Hydrostatic: here the action is displacement controlled and requires some flexibility in the mechanism to allow for any variation in the thickness of the disc. While it is convenient because a force amplification can be achieved, it is somewhat complex and is not as easy to control as the mechanical system.
- Mechanical screw: here the action is also displacement controlled, but it is simple to make and contol.

A screw actuator with a fine thread was used in this device and provided an easily adjustable method of setting and controlling the load with one hand wheel. A stiff rubber spring was incorporated into each brake pad mounting to introduce some flexibility into the mechanism that reduces any variation in clamping force due to a variation in disc thickness and, hence in the load generated by this device.

Drawbar Performance Testing

Animals and Tractors on Firm Soils

Towed vehicle — The conventional method for testing large tractors on firm soils or test tracks is to simulate the implement load by the use of some type of ground driven load vehicle. The basis of operatioon of such a vehicle is the generation of a wheel torque on the vehicle equivalent to the drawbar pull. This requires a corresponding weight of vehicle which, in turn, induces a rolling resistance. This rolling resistance will generally correspond to the minimum draught load which can be achieved, i.e., with the ground drive disengaged.

In the vehicle described here **(Fig. 1)**, the disc brake is mounted on an axle and drive from ground wheels as the vehicle, in the form of a trailer, is towed along. The brake pads and the associated caliper arms, which are carried on the brake arms, are free to float and align with the disc. The (tangential) force on the brake arms is reacted through and measured by the force-cell, which is in turn anchored to the frame.

Calibration — The vehicle with Chevron type tyres was calibrated by towing it on three surfaces and measuring the actual towing force and the force in the cell while generating a load. The results **(Fig. 2)** show the ideal relationship and also that the effect of the rolling resistance, which is not measured by the force cell, can be included as a correction.

During this calibration, the vehicle developed a draught load of 32% of its weight on gravel, firm soil and bitumen for wheel skids of 12, 6 and 5%, respectively. If it is assumed that tractors develop a similar drawbar pull (as % of weight), as does the load vehicle in developing draught, then the vehicle should have the same weight on its wheels as the tractor does on its driving wheels.

Tractors on Soft Soils

Pull-out rig — While a towed vehicle with a ground drive system is suitable for use on firm soils, with soft soils the weight necessary to generate the maximum drawbar pull will cause considerable sinkage. This will in turn cause a rolling resistance which exceeds the minimum draught that is desirable if the full range of pulls is to be explored in the testing work. In order to cope with these problems, a modified form of load vehicle is necessary for testing tractors under soft soil conditions.

The most important aspects in the design of such a rig are that it has a minimum draught of zero and that it does not travel over the soil, but generates the load remote from the test tractor, e.g., while it is situated on the bank or mounted on an anchor tractor at one end of the test area. The test tractor travels across the area and is subject to a draught controlled from the stationary loading rig.

The present device **(Fig. 3)** converts the linear drawbar pull into a torque by means of drum and cord system. Thus the tractor pulls the cord, which unwinds from the drum, against the action of an energy absorbing device that provides a constant but adjustable

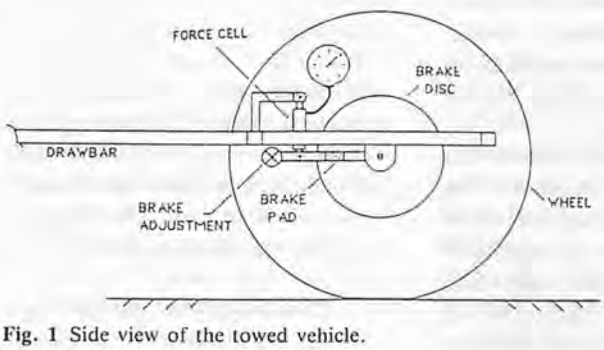

Fig. 1 Side view of the towed vehicle.

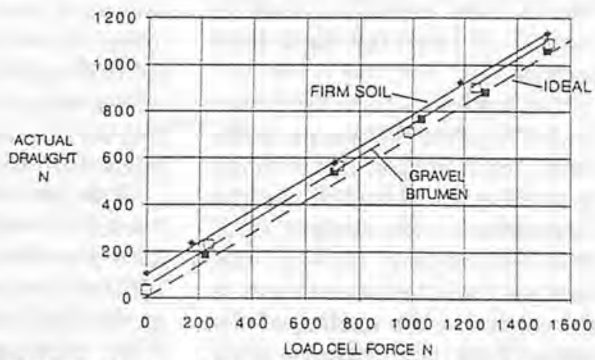

Fig. 2 Calibration of the towed vehicle on three surfaces.

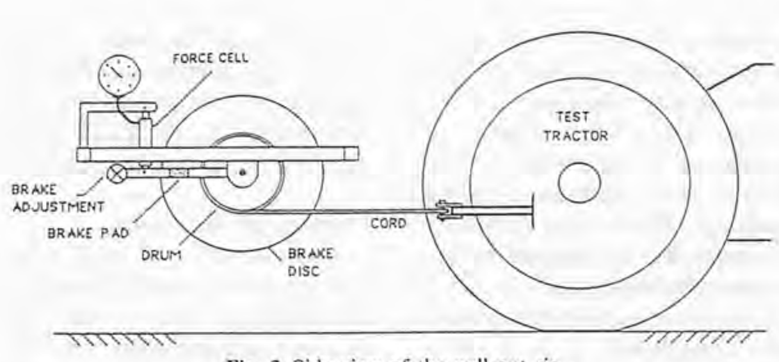

Fig. 3 Side view of the pull-out rig.

load. Based on this method of operation, this arrangement is termed a 'pull-out' rig. The minimum draught is sensibly zero because the friction torque in the bearings that support the drum shaft is negligible.

The drum, together with the brake disk and the brake arms, were mounted on the main shaft, as for the towed vehicle. These components were mounted on a frame, which in turn was mounted on the three-point linkage of a supporting or anchor tractor. When using the rig, it is convenient to locate it so that it can be moved along the side of the test area and so allow the test tractor to operate while moving away from the load rig. It is also necessary to arrange the height of the rig so that when the test is being conducted the cord is horizontal.

Because of its mechanical nature, the performance of a tractor does not vary significantly with time. Hence, on a uniform test area, it is only necessary to measure the performance of the tractor over a short period of time (a minute or two) for each load setting.

Calibration — The use of the device involves the measurement of the reaction force on the brake pads using the force cell and the calculation of the draught load. The relationshiop between this draught load (the tension force in the cord) and the reading of the output from the force cell is given by:

Draught = (Force cell × radius of brake torque arm) / (rad. of drum + rad. of cord)

Assuming that the force cell has a linear output, this relationship will also be linear because all of the terms are constant.

The rig was calibrated by measuring the pull-out force to unwind the cord from the drum while the brake was applied. Forces that cover the range of drawbar pull of animals and walking tractors (from 250 N to 2 500 N) were regressed against the force observed at the force cell to obtain the relationship and hence the draught load.

Conclusion

Testing and research on both animals and small tractors is frequently limited by the lack of suitable equipment for controlled loading of these power sources. The development of a small disc brake and associated torque measuring system provided the basis for two loading systems - a towed vehicle for tractors and animals on firm surfaces and a pull-out rig for tractors on soft soil.

Both systems were used in the testing of walking tractors. The latter generated a draught of up to 1 950 N for a tractor of mass 295 kg working on firm soil, and 1 520 N for a tractor of mass 320 kg working on puddled soil. The details of this work will be published in Part II of this paper. The towed vehicle also operated satisfactorily in informal load tests on a medium draught horse.

Copies of the Manuals (Macmillan, 1991a,b) giving details and drawings for the construction of both the load vehicle and the pull-out rig are available from the authors.

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Performance Evaluation of Hand-operated Seed Planters in Light and Medium Soils in Nigeria

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Abstract

Planting of farm crops by the peasant farmers in Nigeria is done manually. The traditional practice suffers from low output per man-hour and is also very tedious. A study was undertaken to compare the performance of three different models of Jab planters with the traditional method of planting. This paper briefly describes the constructional details and results of field evaluation of the different devices tested. In terms of the field capacity and labour requirements, there was not much difference between the traditional planting method and the Jab planters. However, back-ache and fatigue were completely eliminated while using the planters. Furthermore, all the three models of the Jab planters required further modifications for better performance.

Introduction

Prominent among the field crops planted in Nigeria are maize, cowpeas, soybeans, groundnut, cotton, sorghum, okra, and kenaf. With the exception of the large mechanized farms which use imported tractors and planters, planting of almost all crops on small and peasant farms in Nigeria is carried out manually. Nearly 90% of the food is produced by such farms. The stooping posture during planting leads to backache, fatigue and reduced work output. In the traditional method of planting, a hole is made by a wooden stick, hoe, cutlass, hand, heel or toe of the foot and 2-3 seeds are dropped into the hole and covered with loose soil. The traditional method is slow and tiring due to constant bending of the person while dropping the seeds. In order to eliminate the negative side effects of the traditional method of planting, the National Centre for Agric. Mechanization (NCAM), Illorin in Nigeria acquired two types of hand-held Jab planters for evaluation, trials and possible adoption.

Methods and Materials

The study relates to the performance evaluation of three different types of manually-operated seed planters. Two units were imported and one was developed at the NCAM. One imported unit was an Italian Jab Planter manufactured by M/s Ocmus sbuelz spa, Construzioni Machine Agricole, Brevettate 3310, Udine. It used a metering device with replaceable horizontal seed plate with cells mounted at the base of a cylinderical seed hopper. Six plates to plant seeds of different sizes were provided with the unit. This planter was equipped with a rectangular soil opener. The details are shown in **Fig. 1**. The second imported unit was the AIT Jab Planter obtained from the Division of Agril. Engg., Asian Institute of Technology, Bangkok, Thailand. It consisted of a vertical rotor with two seed cells of different sizes on the periphery to enable planting different sizes of seeds. This planter comprised a seed tube, a compression spring, a push rod and a shovel-type soil opener. Its details are shown in **Fig. 2**. The third unit used for the study was the NCAM developed semi-automatic hand planter. It is comprised of a seed funnel, a seed tube, a handle, a compression spring, a depth regulator, a seed space marker and a jaw-type soil opener. While working, the unit was held in one hand and the seeds were dropped by the other hand. Thus, seed metering was manual and one could drop 1 or more seeds in the seed funnel to plant at a given spot. The opener was thrust in the ground by holding the planter at an angle. Thereafter the seed tube was pushed forward. The movable jaw of the soil opener opened and the seed was

Fig. 1 Italian fully-automatic manually-operated Jab planter in operation (Planter I).

Fig. 2 AIT fully-automatic manually-operated Jab planter in operation (Planter II).

Fig. 3 NCAM semi-automatic manual seed planter (Planter III).

ANNEXURE I. Test Conditions

Item	Planter I	Planter II	Planter III	Taditional method
Date of test		16/8/89, 30/8/89, 4/9/89		
Field condition				
Location		NCAM test plot		
Kind of field		Square		
Area of field (m^2)		100		
Type and characteristic of soil		Sandy loam		
Average soil moisture (dry basis %)		7.40/5.89/5.5		
Cone Index (kg/cm^2)		1.59/1.40/1.8		
Bulk density (g/cm^3)				
Condition of seed				
Type of seed		Yellow maize		
Variety		S123		
Size of seed				
i) Length (mm)		10.5		
ii) Width (mm)		8.9		
iii) Thickness (mm)		4.34		
Weight of 100 (g)		270		
Preparation of seed		Fernasadin		
Viability test (%) (Lab. Germination rate)		89		
Condition of Machine				
Type of metering system	metering disc	Roller	hand metering	Hand
Number of seeds delivered by one hand action	2	2	2	2
Estimated delivering rate (kg/ha)				
(a) at row spacing (g/10m)	25	25	25	25
Percent of damaged seeds (%)	Nil	Nil	Nil	Nil
Methods of seed covering	covering device	by hand	covering device	by hand
Pattern of seed deposition or seed placement pattern	rectangular	conical	jaw	shape undefined
Condition of Operation				
Skill of operator	Average	Average	Average	Highly skilled
Wage of operator (₦ day)	10	10	10	10

released into the ground. With the NCAM planter one could drop the seed in the seed tube while shifting the unit from one planting spot to another. Punching of the hole and releasing of the seed were done simultaneously. The details of the NCAM planter are shown in **Fig. 3**. All these three units were operated in a standing posture.

A comparative field evaluation of all three units was carried out along with the traditional method of planting. The units were first calibrated in the laboratory with a view to adjusting them to drop the seeds properly without causing any injury to the seeds. The units wre tested in a well-prepared seedbed. The seedbed preparation included ploughing the field once with a disc plough and harrowing twice with a disc harrow. It was the standard practice for seedbed preparation under mechanized farming. The viability of the seeds was tested before hand.

All three units were evaluated for planting the maize crop in sandy loam soil No herbicide or fertilizer was applied. The planting of the seeds was done on a flat surface. Moisture content, cone index, rate of planting, depth of planting, frequency of seed dropping and plant emergence after 2 weeks were observed for all the units.

Results and Discussion

The comparative performance tests of the three planters along with the traditional planting method were conducted extensively for maize seed planting.

As evident from **Table 1**

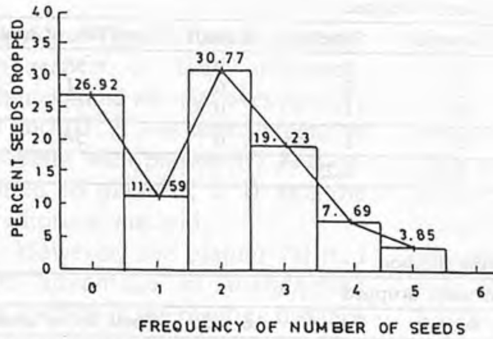

Fig. 4 Percent seeds dropped vs frequency of number of seeds, Planter 1.

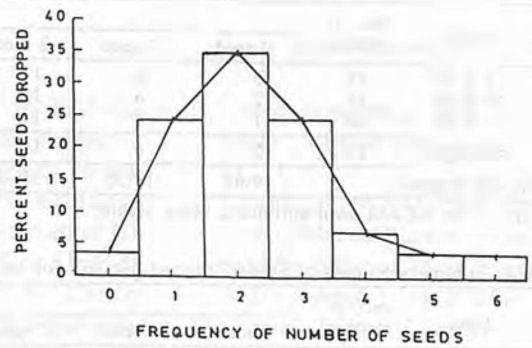

Fig. 5 Percent seeds dropped vs frequency of number of seeds, Planter 2.

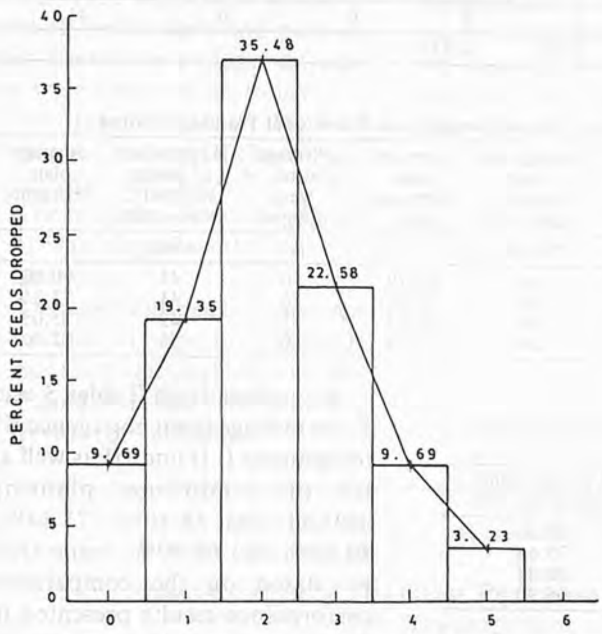

Fig. 6 Percent seeds dropped vs frequency of number of seeds, Planter 3.

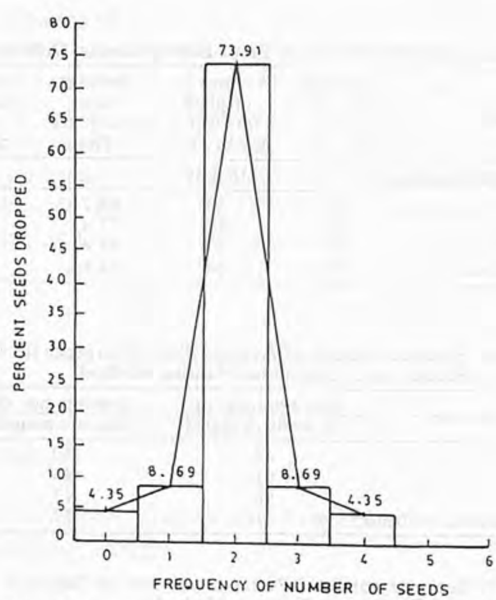

Fig. 7 Percent seeds dropped vs frequency of number of seeds, Traditional Planting Method.

Table 1. Summary Results of Seeds Dropped per Hill for Planter I*

Sr. No.	Date	No. of strokes	Frequency of seeds dropped: 0 seed	1 seed	2 seeds	3 seeds	4 seeds	5 seeds	6 seeds	Total No. of seeds
1.	16.8.89	36	12	3	8	4	0	1	0	35
2.	30.8.89	31	3	4	9	5	3	0	0	49
3.	4.9.89	31	6	3	7	6	3	1	0	50
	Average	33	7	3	8	5	2	1	0	45
Percent seed dropped			26.92	11.54	30.77	19.23	7.69	3.85	0	

*Refers to the Italian Jab planter.

Table 2. Summary Results of Seeds Dropped per Hill for Planter II*

Sr. No.	Date	No. of strokes	Frequency of seeds dropped: 0 seed	1 seed	2 seeds	3 seeds	4 seeds	5 seeds	6 seeds	Total No. of seeds
1.	16.8.89	27	2	4	11	7	2	1	1	62
2.	30.8.89	30	0	7	8	9	3	0	0	64
3.	4.9.89	32	0	11	12	6	0	0	0	56
	Average	30	1	7	10	7	2	1	1	61
Percent seed dropped			3.45	24.14	34.48	24.14	6.89	3.45	3.45	

*Refers to the modified AIT Jab planter.

Table 3. Summary Results of Seeds Dropped per Hill for Planter III*

Sr. No.	Date	No. of strokes	Frequency of seeds dropped							
			0 seed	1 seed	2 seeds	3 seeds	4 seeds	5 seeds	6 seeds	Total No. of seeds
1.	16.8.89	35	5	8	11	5	3	1	0	55
2.	30.8.89	32	2	6	12	10	3	0	0	61
3.	4.9.89	29	1	4	11	6	3	1	0	57
	Average	32	3	6	11	7	3	1	0	58
Percent seed dropped			9.68	19.35	35.48	22.58	9.68	3.23		

*Refers to the NCAM semi-automatic hand planter.

Table 4. Summary Results of Seeds Dropped per Hill for the Traditional Planting Method

Sr. No.	Date	No. of strokes	Frequency of seeds dropped							
			0 seed	1 seed	2 seeds	3 seeds	4 seeds	5 seeds	6 seeds	Total No. of seeds
1.	16.8.89	23	1	6	9	4	1	0	0	37
2.	30.8.89	22	0	1	21	1	0	0	0	45
3.	4.9.89	20	0	0	20	0	0	0	0	40
	Average	22	1	2	17	2	1	0	0	41
Percent seed dropped			4.35	8.69	73.91	8.69	4.35			

Table 5. Summary Results of Plant Emergence for Different Types of Manual Seeders and Traditional Planting Method

Planter	Average total no. of seeds dropped	Average no. of plant emerged 2 weeks after	Average plant emergence (%)	Average total no. of seeds dropped	Average no. of plants emerged 2 weeks after	Average plant emergence (%)	Average total no. of seeds dropped	Average no. of plants emerged 2 weeks after	Average plant emergence
Date of Planting		16.8.89			30.8.89			4.9.89	
I	35	30	85.71	49	44	89.79	50	45	90.00
II	62	48	77.42	64	45	70.31	56	41	73.21
III	55	47	85.45	61	44	72.13	57	49	85.05
Traditonal method	37	24	64.86	45	24	53.33	40	33	82.50

Table 6. Summary Results of Average Plant Emergence for Different Types of Manual Seeders and Traditional Planting Method

Planter	Average total no. of seeds dropped	Average no. of plants emerged	Average plants emergence (%)
I	45	40	88.50
II	61	45	73.64
III	58	47	80.88
Traditional method	41	27	66.90

Table 7. Summary of Field Performance Test of Different Types of Manual Seeders and Traditional Planting Method

Item	Planter I	Planter II	Planter III	Traditional method
Row spacing (cm)	75	75	75	75
Average Depth of seeding (cm)	5.1	4.25	6.3	4.2
Working width of planter (cm)	3.11	3.16	4.7	N.R.
Actual planting time (min)	14.13	15.40	21.24	18.6
Idle time (min)	0.46	—	3.08	—
Seeds covering time (min)	5.07	8.13	5.34	—
No. of hills per row	33	30	32	22
No. of uncovered hills per row	3	30	7	—
Planting speed (m/sec)	0.173	0.157	0.130	0.118
Seed rate (kg/ha)	24.00	25.00	28.67	14.00
Field capacity (ha-h)	0.0315	0.027	0.021	0.034
Field efficiency (%)	91.5	57.48	84.19	—
Labour requirements (man-h/ha)	32.26	37.04	47.62	29.41
Cost of planting (₦/ha)	38.39	45.93	59.6	34.43

*Traditional planting method was the control.

(**Fig. 4**), planter I dropped 0 to 5 maize seeds with an average of 0.97 to 1.61 seeds/hill drop. **Table 2 (Fig. 5)** shows that planter II dropped 0 to 6 seeds with an average of 1.72 to 2.30 seeds/hill. **Table 3 (Fig. 6)** shows that planter III dropped 0 to 5 maize seeds with an average of 1.57 to 1.97 seeds/hill. **Table 4 (Fig. 7)** gives the results of the traditional planting method in which 0 to 4 maize seeds with an average of 1.61 to 2.05 seeds/hill were dropped.

As evident from **Tables 5** and **6**, the average plant emergence E* for planters I, II and III as well as for the traditional planting method was 88.50%, 73.64%, 80.88% and 66.90%, respectively. Based on the comparative performance results presented in **Table 7**, the field capacity of planters I, II, III and the traditional method was 0.031, 0.027, 0.021 and 0.034 ha/h, respectively. The labour requirement for planting one hectare of field with planter units I, II, III and the traditional method was 32.36, 37.04, 47.62 and 29.41 man-h/ha, respectively.

From the field capacity and labour requirement data presented in **Table 7**, it was evident that the traditional planting method had slight edge over the three planters when tested on a small area. But for planting a large area, the results could be different, considering the drudgery and backache experienced by the persons

*Percent Plant Emergence = (Average of plant emerged per row) / (Average of total seeds dropped per row) × 100 employed for traditional planting. In respect of field efficiency, planter I had an edge over planters II and III. It was more expensive to plant with planter III as compared to planters, I, II and the traditional method.

However, the planter III had the advantage of maintaining uniformity in the planting distance over planters I, II as well as the traditional method.

All three units were found to worked well in light and medium soils. Certain operational difficulties were observed as follows:

1. The jaws of planter III were clogged with soil if the soil was too wet and heavy;
2. The metering device of planter II was clogged with seeds frequently;
3. The plant-hill spacings were not uniform in respect of planter II and the traditional method; and
4. Planter II had no covering device for the seeds.

Conclusions

All the three planters had the advantage of eliminating the backache problem encountered in the traditional method of planting. Even though the cost of planter III was much less (₦ 100 or US$10) than planter I and II (₦ 200 or US$20 each), these two planters had the advantage of planting the seeds faster. Planter III was more rigidly built than the other two planters. Planter II lacked a covering device and as such there was need for modification. In terms of rate of planting there was not much difference in the three units tested. If the NCAM semi-automatic planter could be modified to meter the seeds automatically, it would be possible to enhance its speed of planting and field capacity.

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Development and Adaption of No-till Technology for Sowing Wheat

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Abstract

Wheat sowing is delayed in the rice-wheat zone of Punjab, Pakistan due to the late maturity of Basmati rice. To avoid this, intensive efforts were made to test, evaluate, and introduce direct drilling of wheat in rice stubbles soon after paddy harvest. Experimental studies indicate that direct drilling of wheat after paddy harvest produced 24% higher yield than wheat sown with conventional tillage.

This paper concentrates on the adaption of no-till technology in paddy-wheat zone of Punjab, Pakistan. The work done at the Farm Machinery Institute (FMI), Islamabad, related to the design and development of low-cost, no-till drill for wheat sowing and the impact of introducing no-till technology is discussed.

Introduction

Wheat is the most important food grain crop of Pakistan. It is sown on about 8 million ha of land, and its production is about 15 million mt per annum. It is the national priority to increase its production at a rate of 3%/annum to meet the demand of the growing population. Since the Green Revolution, the increase in wheat production has been brought about largely by sowing high yielding varieties, increasing areas under wheat crop and fertilizer use, and greater availability of irrigation water **(Table 1)**. The table also shows that wheat production has increased many fold since 1960, but its production is almost stagnant since 1988. However, experts have recognized that further increase in wheat production now depends upon better tillage and sowing techniques, timely sowing, control of weeds and pests and efficient use of fertilizers and water (Aslam et al, 1989).

Table 1. Wheat Production Pattern in Pakistan

Year	Fertilizer Use* (kg/ha)	Area Planted to Wheat (million ha)	Production (million t)
1960	NA	4.6	3.8
1965	NA	5.1	3.9
1970	15	5.9	6.4
1975	28	6.1	8.6
1980	53	6.9	11.4
1985	86	7.4	13.9
1986	83	7.8	12.1
1987	83	7.3	12.6
1988	NA	7.7	14.4
1989	NA	7.5	14.3
1990	NA	7.8	15.1

Source: Economic survey 1990-91.

Wheat is sown after the paddy crop on about 1.1 million ha in the Punjab province of Pakistan. Eighty percent of this area is planted to Basmati-370 rice, a photoperiod sensitive, fine quality, desi-type variety. This variety does not mature until mid-November, and many farmers do not harvest it until December (Majid et al., 1988), which delays wheat sowing. Late sowing of wheat is the major reason for low wheat yields in this cropping pattern. Hobbs (1985) predicted wheat yield losses of 35 to 40 kg/ha day when wheat not sown before November 20. The Coordinated Wheat Programme of the National Agricultural Research Centre (NARC) made intensive efforts in conducting experiments about direct drilling of wheat in rice stubbles. Their studies indicate that direct drilling of wheat after paddy harvest produced 24% higher yield than wheat sown under the conventional tillage. This difference is due to the nearly 24-day post-harvest period required for conventional tillage/sown operations (Aslam et al, 1989).

The concept of no-till implies direct sowing into the soil that is covered with plant residue or stubble. Sowing is done with minimum soil disturbance. Muhtar (1986) stated that no-till reduces soil erosion, permits better timeliness of all crop management operations, reduces total inputs on the farm, because of lesser time, labour, and fuel consumption. To strengthen the concept of low input sustainable agriculture, the scientists, engineers and farmers are challenged to increase agricultural production without increasing the use of fossil fuels (Bowers, Jr., 1985).

This paper concentrates on the adaption of no-till technology in paddy zone of Punjab, Pakistan. The work was done at the Farm Machinery Institute (FMI), NARC, Islamabad. It is related to the development of low-cost, no-till drill for wheat planting and the impact of introducing non-till technology.

Adaption of No-till Technology

The Coordinated Wheat Programme of the Pakistan Agricultural Research Council (PARC), conducted on farm experiments to evaluate, verify and demonstrate the no-till technology from 1984-85 to 1987-88. They compared the no-till technology with the farmers conventional practices. In no-till plots, no land preparation was done and wheat was sown directly in the standing paddy stubble with an Aitchison Seedmatic Drill. Whereas in the conventional practices, fields are tilled 4 to 8 times before broadcasting the wheat seed. All other levels of inputs were kept constant. The following were the findings (Aslam et al, 1989):

1. Wheat in no-till conditions produced a significantly higher number of tillers/m^2 than that under conventional tillage.
2. On the average, wheat can be sown about 24 days earlier with direct drilling method as compared to conventional practices. Therefore, about 24% higher wheat yield were obtained from the no-till plots.
3. Where the wheat sowing dates varied little between direct drilled wheat and farmers practices, there was no significant difference in wheat yield.
4. Forty-three % lower weed densities were observed in direct drilled fields as compared to the conventional practices.

No-till experiments were conducted on 42 farmers' fields. These farmers were personally interviewed concerning their views about the technology (Aslam et al, 1991). On many locations farmers stated that yield of no-till sowing was at par/or more as compared to the conventional practices. On the locations where it was possible to sow earlier with no-till technique, the yield of wheat was higher than yield obtained from farmers using the conventional practices. Therefore, the farmers were convinced to sow wheat with no-till technology, but they were worried about the availability of suitable drill.

The Coordinated Wheat Programme of PARC, initially sowed wheat in their experiments using imported Aitchison drill from New Zealand. After successful trials it was decided to introduce this technology on large scale. However, Aitchison drill was very expensive (Rs. 150 000 (US$6 000)/unit), and could not be operated with commonly available medium size tractor (37 kW). The FMI of PARC took the responsibility of designing and developing a low cost no-till drill, suitable to the local conditions of paddy-wheat zone of Punjab, Pakistan.

Development of Low-cost No-till Drill

The CIMMYT and crop maximization programme of PARC imported two seed-cum-fertilizer drills. These were 1116 Aitchison and SPSC/200-NARDI manufactured in New Zealand and Italy, respectively. The Aitchison drill was multicrop and has provision for fertilizer application. It is very precise in metering and placing of seeds and fertilizer in tilled and no-tilled soil, but very expensive and beyond the means of majority of the farmers. The DESCON Engineering locally fabricated the Aitchison drill using imported gear box and depth control wheels, with financial assistance from the United States Agency for International Development (USAID). The DESCON drill was also not suitable because of its high price (Rs. 50 000 (US$2 000), heavy weight and other manufacturing problems. Therefore, the challenging task was given to the Farm Machinery Institute's engineers to design and develop low-cost, light weight, no-till drill with the following design parameters:

a. The price of the drill should not be more than Rs. 20 000 (US$800).
b. It can be operated with commonly available 35 kW tractor.
c. The drill can place seeds at an appropriate depth in tilled as well as in no-till conditions.

Fig. 1 FMI Low-cost no-till drill.

Table 2. Comparison of Salient Features of Different Versions of No-till Drill

Parameter	Aitchison Design	DESCON Design	FMI low-cost no-till drill
Empty weight (kg)	610	540	370
Volume of seed box (m^3)	0.28	0.21	0.12
Volume of fertilizer box (m^3)	0.31	0.24	0.12
Power required (kW)	56	48	35
Working width (m)	2.4	1.8	1.8
Field capacity (ha/h)	0.54	0.40	0.40
Price	150 000	50 000	20 000
Operational cost (Rs/ha)	810	530	330

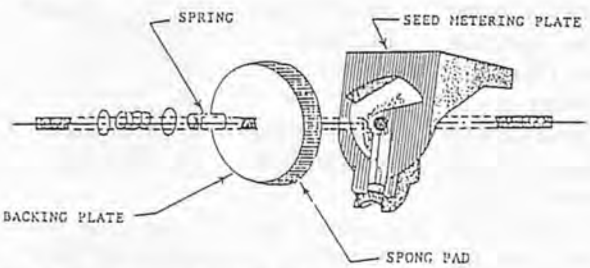

Fig. 2 Seed metering system of low-cost drill.

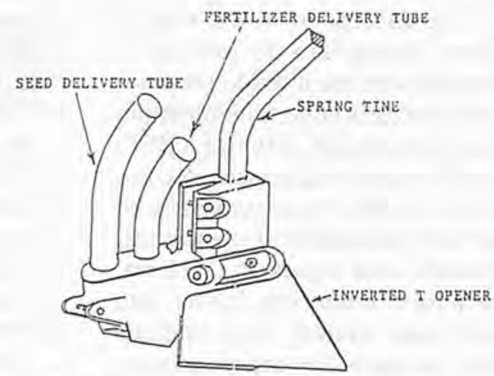

Fig. 3 Seed and fertilizer placement unit.

d. It should be able to meter the fertilizer at various rates and at an appropriate depths below the seed.

e. It can be manufactured in Pakistan using indigenous technology.

Keeping in view the above design parameters, a low-cost no-till drill was designed and developed at the Farm Machinery Instituute, Islamabad. The approach used for design and development of drill was well presented by Ahmad et al., 1992. The drill has all the basic features of the Aitchison drill, but it is light weight, and its price is about one-sixth of the Aitchison drill. **Fig. 1** shows the FMI low-cost, no-till drill. **Table 2** compares the salient features of different versions of no-till drills. The beauty of the drill is that it has sponge feed mechanism (**Fig. 2**), which can drill a wide variety of crops. Furthermore, its seed and fertilizer placement mechanism is based on inverted "T" furrow opener (**Fig. 3**). The furow opener creates soil micro-environment better suited for seed germination, can drill in both tilled and untilled soil, and can handle residue or trash left from previous crop (Chaudhary, 1988).

Field Evaluation of Low-cost No-till Drill

The FMI-designed no-till, multi-crop drill was field tested during the wheat sowing season of 1991 at Gujrat, District of Punjab. About 45 acres were sown with this machine. The parameters related to the field conditions were measured and presented in **Table 3**. The average moisture content and Cone Index (CI) valves at 15 cm depth was 15.6% and 3 130 KPa, respectively. The test result for the new drill is shown in **Table 4**. The drill was tested in plots with an average size of 0.48 ha, and the machine was operated on headland pattern. The effective field capacity of the machine was 0.4 ha/h whereas the field efficiency was 45%. The reasons for low field efficiency were the small size of plots, and time lost during turning at headlands (Ahmad et al, 1992). The stability of medium size tractor (MF-240)

Table 3. Characteristics of Field Conditions

Item	Values
Soil type	Clay loams
Moisture content (%) (top 15 cm)	15.6
Tilled or un-tilled	Un-tilled
Average cone index at 15 cm depth (kPa)	3 130
Height of rice stubble	
Minimum (cm)	7.5
Maximum (cm)	20.0
Average (cm)	15.0

Table 4. Test Results of Low-cost, No-till Multi-crop Drill

Parameter	Values
Power source	40 kW tractor
Number of tests	5
Average size of test plot (ha)	0.48
Crop	Wheat
Average travel speed (km/h)	5
Working width (m)	1.8
Effective field capacity (ha/h)	0.40
Field efficiency (%)	45
Fuel consumption (ℓ/h)	2.6
Average depth of seed placement (cm)*	6

*Depth of seed placement is adjustable

was improved with the FMI drill as compared with the DESCON drill. This was achieved by designing FMI drill light weight, and moving its centre of gravity closer to the rear wheels of the tractor. The results of the field evaluation indicate that the low-cost, no-till drill is best suited to the agro-climatic conditions of paddy-wheat zones of Punjab, Pakistan.

Operational Cost of the No-till Drill

The operational cost of low-cost, no-till drill was predicted, along with the operational cost of DESCON and Aitchison drill. This comparison was made to identify the benefits achieved in terms of reduction in operational cost, by designing the low-cost, no-till drill. The cost calculations are presented in **Table 5**. These cost calculations were based on the assumption that each drill will operate 240/h annum, for a period of 5 years. The annual use of each tractor was assumed 1 000 hours per annum. The low cost drill can be operated with 35 kW (MF-240) tractor whereas the DESCON and Aitchison drill require more than 50 kW tractor. The fixed costs of MF-240 and MF-375 were also calculated. The cost of sowing with low cost drill was Rs. 330/ha (US$ 13/ha), as compared to Rs. 530/ha (US$21/ha) and Rs. 810/ha (US$32/ha) for DESCON and Aitchison drill, respectively. This means that a significant reduction in operational cost was also achieved by designing the low cost no-till drill.

Table 5. Comparative Costs of Sowing with Different Versions of No-till Drill

Item	Tractors		Drills		
	MF240	MF375	Low-cost	DESCON	Aitchison
Purchase cost (Rs)	198 500	294 500	20 000	50 000	150 000
Useful life (h)	10 000	10 000	1 200	1 200	1 200
(years)	10	10	5	5	5
Salvage value (10%)	19 850	29 450	2 000	5 000	15 000
Fixed cost (Rs/h)					
Depreciation	17.86	26.5	15.0	18.75	112.5
Interest (14% on average investment)	15.28	22.67	6.4	16.00	48.2
Taxes, insurance & shelter (2.5% of initial investment)	4.96	7.30	2.0	5.20	15.6
Repair and maintenance	19.85	29.45	15.0	37.5	112.5
Total fixed cost (Rs/h)	57.95	85.92	38.4	77.45	288.8
Fixed cost (FMI + MF240, DESCON + MF375 & Aitchison + MF375)			96.35	163.37	374.7
Field capacity (ha/h)			0.40	0.40	0.54
Labour input (man-h/ha)			5.00	5.00	4.00
Fuel consumption (ℓ/ha)			7.50	12.50	12.5
Cost (Rs/ha)					
Fixed (including repairs)			240.8	408.4	694.00
Labour @ Rs. 7/h			35.00	35.00	28.00
Fuel (diesel) @ Rs. 6/ℓ			45.00	75.00	75.00
Lubricants (15% of fuel cost)			6.75	14.25	11.25
Total cost (Rs/ha)			330.00	530.00	810.00

Note: Repair and maintenance cost for tractor is 1.0% P/100 h. and for drill is 7.5% of P/100 h.

Indigenous Production of No-till Drill

One of the most important design parameters was that the drill could be manufactured locally in order to ensure its availability. To achieve this, the PARC signed an agreement with the Green Land Engineers, Daska, for local manufacturing of low-cost no-till drill. The FMI will provide technical assistance to the Green Land Engineers, for the production/commercialization of the low-cost, no-till drill.

Economics of the No-till Technology

Table 6. Economic Comparison of Zero Tillage and Farmer Practises for Wheat Cultivation in Rice-Wheat Zone of Punjab

Operation	Cost in Rupees/ha	
	Zero tillage with FMI drill	Farmers practice
Land preparation		
6 cultivations Rs. 125/ha	—	750
3 plankings @ Rs. 50/ha	—	150
Cost of planting		
2 cultivations and 1 planking	—	300
Drilling	328	—
Planking	50	—
Broadcasting	—	25
Total	378	1 225

- Cost advantage of zero tilage over farmer practice = 1225 − 378 = 847
- Benefits of zero tillage through early planting 20 days (av.) at 30 kg/day/ha = 600 kg × 2.75 Rs/kg = 1 650

Total benefits of zero tillage over farmers practices = 2 497 = 2 500

Source: Wheat Programme, NARC, Islamabad.

Table 7. Fuel Saving Through Zero Tillage over Farmer Practice for Wheat Cultivation in Rice-wheat Zone of Punjab

Operation	Fuel consumption litre/ha	
	Zero tillage with FMI drill	Farmers practice
Fuel consumption for land preparation		
6 cultivations @ 7 litre/ha	—	42.00
3 planking @ 3 litre/ha	—	9.00
Fuel consumption in planting		
2 cultivation & 1 planking	—	17.00
Drilling @ 6.5 litre/ha	6.5	—
Planking	3.0	—
Total	9.5	68.00

- Fuel savings litre/ha = 68.0 − 9.5 = 58.5
- If 60% wheat in rice-wheat zone of Punjab would be sown by no-till technology
- Total fuel saving (Diesel) = 1.1 million ha × 0.6 × 58.5 ℓ/ha = 38.6 million ℓ
- Worth of fuel (Diesel) in Rs. = 231.6 million

An economic comparison of the no-till drill and farmers' practices for wheat cultivation in the paddy-wheat zone of Punjab was undertaken (**Table 6**). The table shows that a farmer can achieve a benefit of Rs. 2 500/ha (US$ 100/ha) by using the no-till technology.

Fuels savings in the use of the no-till technology over farmer practices for wheat cultivation in paddy-wheat zone of Punjab is shown in **Table 7** indicating that about 58.5 ℓ/ha diesel fuel can be saved by direct drilling of wheat in paddy stubble and if 60% of the wheat in the paddy-wheat zone of Punjab would be sown by direct drilling. This will save 38.6 million ℓ of diesel fuel, worth 231.6 million rupees annually.

Conclusions and Recommendations

1. Direct drilling of wheat in rice stubble has great potential in rice-wheat zone of Punjab, Pakistan. This technique is equivalent to conventional practices in regard to wheat yield when the crop is sown at the same time, and economical in terms of resource use.
2. This technique allows the sowing of wheat about 24 days earlier (time required for conventional tillage operation), which results in higher yield (24%) as compared to the conventional tillage practices.
3. The low-cost drill designed and developed at the FMI is technically as well as economically suitable to the local conditions of Pakistan. Its price is about Rs. 20 000 (US$800) as compared to Rs. 150 000 (US$6 000) and 50 000 (US$ 2 000) for Aitchison and DESCON drill, respectively. It is lighter in weight and can be easily operated with commonly available 35 kW (45 hp) tractor.
4. A farmer can achieve benefit of Rs. 2 500/ha (US$100/ha) by using the no-till technology, and if 60% of wheat in paddy-wheat zone of Punjab would be sown by direct drilling. about 38.6 million ℓ of diesel fuel, worth 231.6 million rupees can be saved annually.
5. An agreement had been signed between PARC and Green Land Engineers for the local manufacture of the low-cost drill at commercial scale. The first few units will be available for testing and demonstration for the wheat sowing season in 1992.
6. Extensive efforts are needed for further demonstration and popularization of the no-till technology in the paddy-wheat zone of Punjab, Pakistan. The use of this technology will enourage the concept of low input sustainable agriculture.
7. Efforts should be made to test and evaluate this technology also in the cotton-wheat zone of Punjab.

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An Electronic Implement Depth Sensor

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Abstract

An inexpensive electoronic depth measuring device, suitable for use on a range of soil engaging and other equipment was developed. Tests were conducted to assess its practical applications. Results indicate that the system is a feasible option for a range of operations requiring depth control, such as crop seeding or peat milling. Depth sensing to an accuracy of ±4 mm can be achieved.

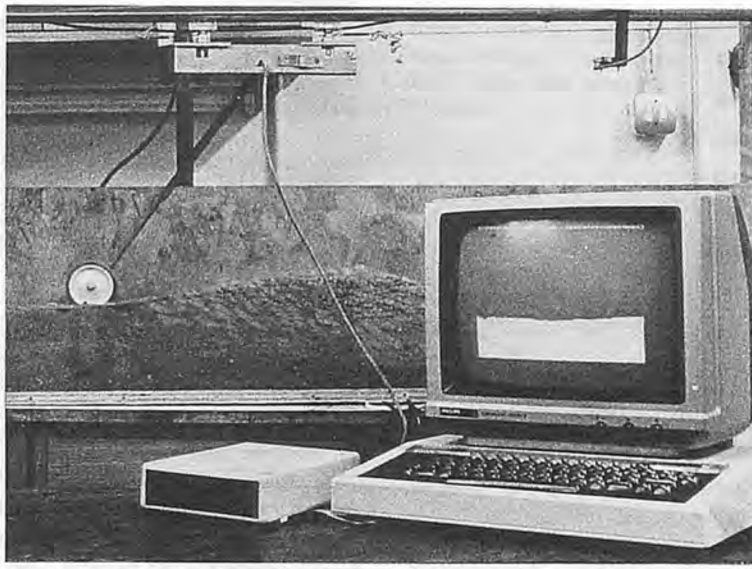

Fig. 1 Photograph of the laboratory simulation unit used to test the device.

Introduction

Recent advances in tractor technology has seen the introduction of electronic sensors and on-board computers. These developoments have come against a background of mechanical implement sensing and control systems, with the result that implement manufactures need to develop electronic control and monitoring systems that can interface with modern tractor electronics.

This paper describes the development of such a system — an inexpensive displacement sensor suitable for use as a depth control system for such operations as crop seeding, cultivation or peat milling operations.

Experimental Rig

A photograph of the device is given in **Fig. 1**. The unit consists of:

1. A rotating potentiometer, attached to a "float" which is the basis of the displacement sensor — a wire wound high resolution potentiometer was selected; and
2. BBC microcomputer, which acts as an analog to digital convertor and as a data processing and display device.

Results

The accuracy of the apparatus was tested by moving the unit across various soil profiles and analyzing the resultant signal viz-â-viz the actual profile. Forward speeds in the range 0.4 to 0.7 m/s

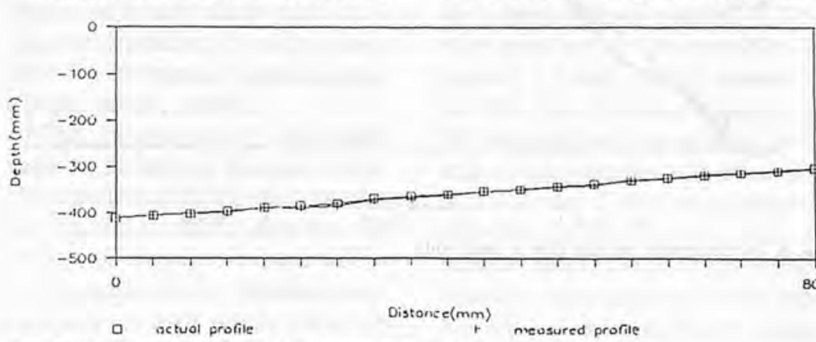

Fig. 2 Displacement profile (for a sandy substrate).

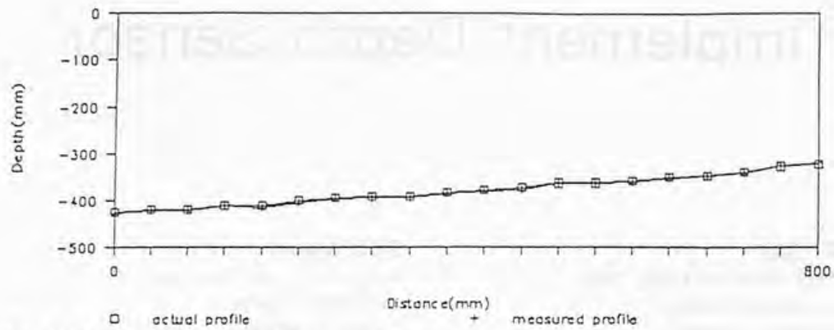

Fig. 3 Displacement profile (for a sandy substrate).

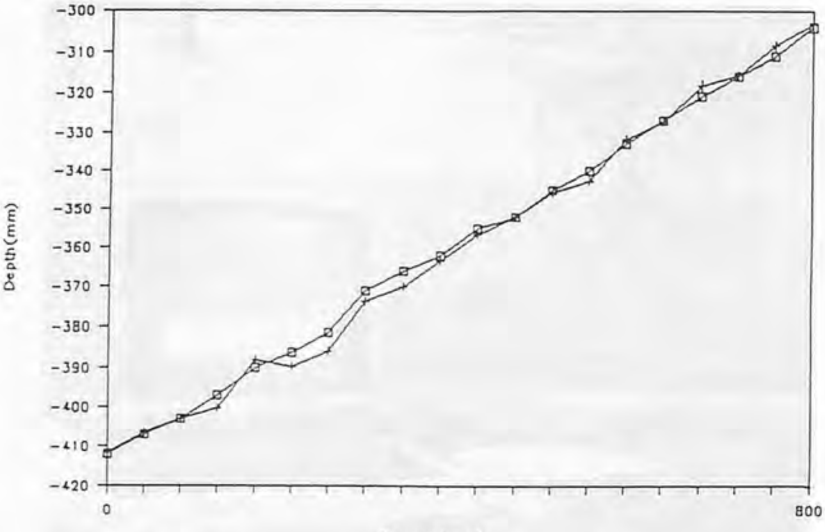

Fig. 4 Displacement profile (for a sandy substrate).

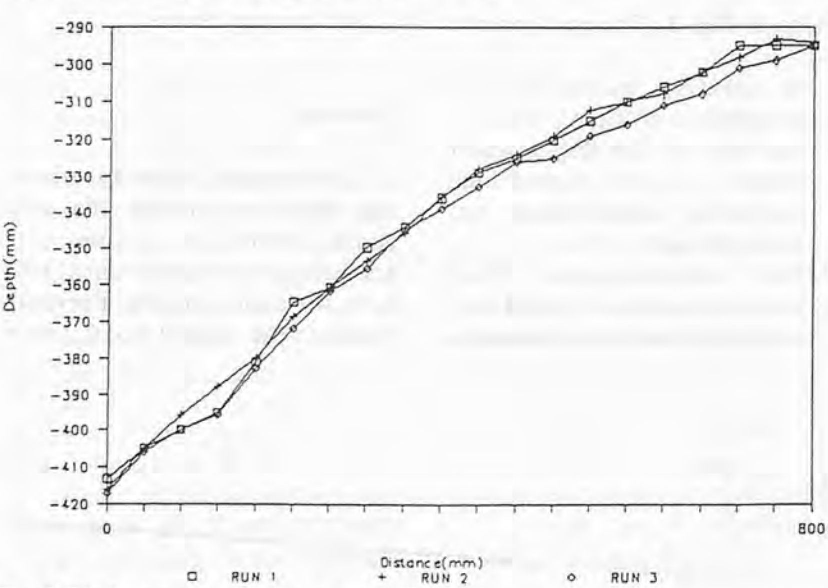

Fig. 5 Displacement profile (for a peat soil).

were used. Results, for various runs of the apparatus, are given in **Figs. 2** to **5**. This shows that:

1. The unit gives consistent results, as shown by the accuracy of fit of the measured versus actual depth **(Figs. 2** to **4)**; and
2. The reproducibility of consecutive runs, on a peat soil **(Fig. 5)**.

The unit is accurate to within approximately 4 mm. The greater error obtained on peat soils is a result of the high compressibility of the substrate. The key success factor in the operation of this unit is the design of the ''float''. For example, for milled peat operations the low bearing pressure of the bog surface mould dictate a low ground pressure device, such as a large diameter wheel or a skid: and the latter is probably the best option.

Discussion

A simple depth control device is described here that has applications in many areas of agriculture, both on and off-farm and, in milled peat production. The unit is capable of sensing depth to within ± 4 mm and, as such, is sufficiently sensitive for almost all possible practical applications. The precise design details are not presented here due to their complexities but these can be obtained from the authors, on request. The single most important design factor is the ''float'' arrangement (both its bearing pressure and unsprung weight) — and it must be designed specifically for each application. ■■

Development of Knapsack Electrostatic Spinning-disc Sprayer for Herbicide Application in Rice

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Abstract

A knapsack-type sprayer with two electrostatic spinning disks was designed and tested for herbicide application in paddy crop. Its performance is as good as that of the knapsack hydraulic nozzle sprayer in controlling weeds in rice crop with added benefits of less operator's exposure to toxic chemicals, less solvent requirement and lighter weight.

Introduction

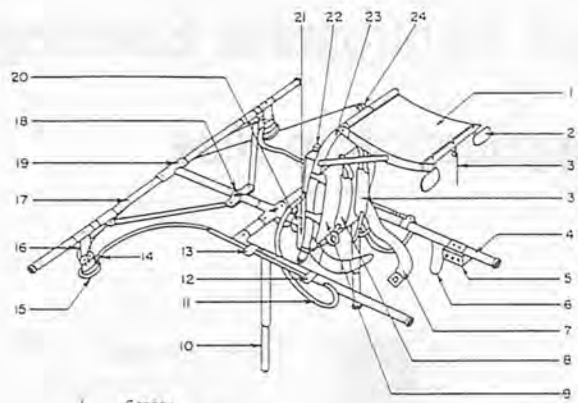
Chemical herbicides application offers a quick and effective method in controlling weeds in rice fields. Its use results in increased yield and, therefore, higher income to the growers. However, the increasing cost of herbicides coupled with the growing public concern to minimize the use of farm chemicals calls for more efficient application equipment than is currently being used.

Research in electrostatic spraying at AIT led to the development of a hand-held electrostatic spinning-disc sprayer suitable for pesticide spray application in small-scale farming system. The electrostatic spinning-disk sprayer combined the principles of controlled droplet application (CDA) and electrostatic charging to increase the spray application efficiency and, therefore, minimize drift. Laboratory deposition studies of the prototype electrostatic sprayer gave up to 2-fold improvement in deposition efficiency on soybean simulated targets (Dante and Gupta, 1991). Field deposition studies show that the electrostatic sprayer had significantly higher deposition in paddy soybean plants and comparable deposition in maize plants than the hydraulic-nozzle sprayer (Gupta et al., 1992).

The objectives of the study were to develop a knapsack-type electrostatic spinning-disc sprayer for herbicide application in rice crop, test its performance under field conditions in Thailand and compare it with some common lowland rice weeding methods, such as hand weeding, mechanical weeding, and chemical application using knapsack hydraulic nozzle sprayer.

Knapsack Electrostatic Spinning-disc Sprayer

Fig. 1 shows a schematic diagram of the knapsack electrostatic spinning-disc sprayer. The main parts are back-pack frame, handle and boom. All frames are made of aluminum pipe with 19-mm diameter and 2-mm thickness. The 40 × 84 cm back-pack frame was S-shaped to match the contour of the operator's back and was padded to provide comfort to the operator. It carried a 5-liter plastic container for the spray solution, a 12 volt DC wet-cell rechargeable battery, and a high-voltage power supply unit (Model C-30 manufactured by Venus Scientific, Inc., NY). A tailored pocket-type cloth holder contain the battery and power supply unit. A canopy was provided at the top of the back-pack frame.



1. Canopy
2. Viewing mirrors
3. Boom height adjusting rope
4. Aluminum handles
5. Power supply switch box
6. Wiring connection from battery to switches
7. Belts
8. Padded chest belt straps
9. Back cushion
10. Stands
11. Plastic liquid lines
12. Liquid flow control valves (left and right)
13. Clip holders
14. Liquid flow inlet to the atomizer
15. ASPEE Spinning discs atomizer — sprayer
16. Disc movable holder
17. Swinging and sliding boom
18. Swath adjuster screw
19. Tensioning rope for supporting and adjusting boom height
20. Backpack and boom connector
21. Cloth holder for the power supply components
22. Liquid tank (5 l)
23. Backpack frame
24. Pulley

Fig. 1 Diagram of knapsack electrostatic spinning-disc sprayer.

Fig. 2 Sprayer converted into pull-along type.

Fig. 3 Knapsack electrostatic sprayer during field trials.

Two viewing mirrors fixed at the front corners of the canopy provide a quick viewing of the sprayer's operation. The back-pack had belts for the shoulders, chest and waist of the operator.

The aluminum-pipe handle and boom were connected to the back-pack frame through nuts and bolts. The right hand side handle had a switch box containing three switches, i.e., a switch for the sprayer motors and two switches to connect the high voltage power supply to the electrode in each sprayer. The liquid lines which run through the handle had a flow control valve positioned near the operator's hand. The unit can be converted into a pull-along sprayer by attaching a skid or wheel in the tube connecting the handle and the boom (**Fig. 2**).

The 2-m aluminum boom carry two electrostatic spinning discs. The spacing between spinning discs can be adjusted by unscrewing the disc holder and sliding it through the boom. There were two ways to change the height of the boom: (1) by pulling the tensioning rope, and (2) by moving up or down the handle. The assembly weighs 8.1 kg with complete accessories such as loaded liquid container, power supply unit, etc.

The electrical wiring connceting the power supply to the sprayers' electrode (to produce the electrostatic charging effect) and motor run through the inside of the aluminum handle and boom. An electrical circuit reduces the input 12 to 6 volts DC required for each motor.

Field Tests

During the field trials, each electrostatic spinning-disc sprayer ran at 1.2 kV electrode potential, 50 mL/min liquid flow rate, and 2000-3000 rev/min disc speed. This provided a spray charge of approximately 1.0 mC/kg (Dante and Gupta, 1990) and about 165 μm mean droplet size as collected on a magnesium oxide coated glass slide and measured with a Fleming Particle Size Analyzer (Dante and Gupta, 1991). A fully charged wet cell battery lasted for three hours of continuous operation. Beyond this period, the disc speed was less than 2 000 rev/min. Swath width varied from as low as 2 m at 2 000 rev/min to 3 m at 3 000 rev/min. **Fig. 3** shows the prototype sprayer used during the field trials.

The actual field capacity of the knapsack electrostatic sprayer was 0.05 ha/h as compared to 0.1 ha/h of the single-nozzle hydraulic sprayer. The relatively lower capacity of the prototype sprayer was due to higher turning and set-up time. The electrostatic sprayer needed 30 min to set-up while the hydraulic nozzle sprayer needed only 5 min. Also, the operator had the tendency to walk slowly when spraying with the electrostatic sprayer as he could hardly see the spray.

Weeding Efficiency

The weeding efficiencies of chemical herbicide application using the electrostatic sprayer were compared with other weeding methods, such as chemical application using hydraulic nozzle sprayer, mechanical weeding using an IRRI (International Rice Research Institute, Philippines) cono-weeder, and manual weeding in broadcast, direct-seeded and transplanted rice fields. The knapsack hydraulic sprayer has a hollow-cone nozzle. The nozzle discharging at 640 mL/min produced droplets of about 300 μm VMD (volume median diameter) as collected on water-sensitive paper and measured with a laboratory microscope. A factor of 1.9 converted spot size into droplet size.

The three experimental rice fields were laid out in randomized complete block design. Each field was divided into three equal blocks, each representing a replication. Each block was further subdivided into five equally-sized and identically-shaped plots where each represented a treatment, i.e., weeding technique. In the transplanted field, 30-day old paddy seedlings (RD23) were manually transplanted with a spacing of 30 × 20 cm at the rate of 3 to 4 seedlings per hill. In the direct-seeded field, an AIT-developed direct seeder (Unadi and Gupta, 1990) seeded the field 15 days after plowing. Two days after preparing the broadcasted field, the same variety of rice seeds were sown manually.

All weeding techniques were carried out almost simultaneously except the mechanical method. The IRRI cono-weeder needed about 15 cm water level in the field to make it work effectively. Thus, mechanical weeding was performed before the spraying operations as water in the field needed to be drained to expose the smaller weeds during chemical application. During the spraying operation, each sprayed plots was blocked with plastic sheets at the borders to avoid spray droplets reaching the adjacent plots. Meteorological data such as wind velocity, humidity and air temperature were constantly monitored using a Kanoxmax anemometer and dry and wet bulb thermometers.

Table 1. Herbicides Used in Field Trials

Name	Description	Type	Recommended Dosage (per rai)
Whip 7.5	a.i. (D+)-ethyl-2-(4-(6-chloro-2-benzoxazolyloxy)-phenoxy)-phopanoate	7.5% W/V (EC)	30-40cc/20 l water
ALO	a.i. (3,4-dichloro-propionanilide)	36% W/V (EC)	1.5-2 l/80 l water
ESONAT 85	(2,4-D sodium salt)	85% WP	28-38 g/20 l water

1 ha = 6.25 rai

Table 2. Weeding Efficiencies of Different Weeding Treatments in Transplanted, Direct-seeded and Broadcast Field.

Weeding Treatment	Weeding Efficiency (%)		
	Transplanted	Direct-seeded	Broadcasted
Manual weeding	100	100	—*
Mechanical weeding	63	87	—
Chemical spraying:			
- hydraulic nozzle	89	77	89
- electrostatic sprayer	86	75	90

*Manual and mechanical weeding were not conducted in broadcast field.

The type of chemical and dosage selected were based on the type and population of weeds in the field. The most dominant weeds in the experimental fields were *Sphenoclean zeylanica gaertn.* (broadleaf) and *Cyperus difformis linn.* (narrow leaf). Herbicides used to control these weeds are described in **Table 1**. The volume of herbicide formulation required in the experiment was calculated using the expression (RAO, 1987)

$$H_f = \frac{R\ A\ n * 100}{D * 10000}$$

where:

H_f = formulation required in kg in one experimental field

R = recommended rate (kg. active ingredient per ha)

A = area of plot (m^2)

n = no. of plots in one experimental field

D = % of active ingredient in the formulation

Weed population before and after weeding operation in each replication was counted. Weeding efficiency was then calculated using

$$\text{Weeding Efficiency} = \frac{W_1 - W_2}{W_1} \times 100$$

where:

W_1 = weed population before weeding

W_2 = weed population after weeding

In the transplanted field, the mean weeding efficiencies from chemical spray application were significantly ($P < 0.05$) higher than mechanical weeding **(Table 2)**. There was no significant ($P < 0.05$) difference between the two chemical spray application techniques. In the direct-seeded field, the mechanical weeding treatment gave significantly ($P < 0.05$) higher weeding efficiency than any of the chemical spray application technique. In the broadcast field, no statistically significant ($P < 0.05$)

Fig. 4 Knapsack electrostatic sprayer with plastic shields.

Table 3. Spray Deposition Over Operator's Body with Prototype Elecstostatic Sprayer and Hollow-cone Hydraulic-nozzle Sprayer

Spraying Technique	Mean droplet density (no. 1 per cm^2)*					
	Head	Nose	Face	Stomach	Arms	Legs
Electrostatic sprayer	0	0	0	0	27	38
Hydraulic sprayer	65	45	52	25	25	50

*Mean of three measurements.

Table 4. Spray Deposition into Operator's Body with Prototype Electrostatic Sprayer With and Without Shield

Treatment	Mean droplet density (number per cm^2)*					
	Head	Nose	Face	Hips	Arms	Legs
With shield	0	0	0	12	5	24
Without shield	0	0	0	16	5	38

*Mean of three measurements.

difference in weeding efficiency between chemical spray application method was detected.

Operator's Exposure to Spray Drift

In this test, water-sensitive papers were pasted in different parts of the operator's body to detect the spray deposition while spraying. The number of spots in the paper was counted using a linen tester lens with droplet counting cards (Ciba-Geigy). A drift test was also conducted to assess whether shielding of the sprayer could reduce the operator's exposure to spray drift. A 1-m diameter disc-shaped shield framed with 2-mm diameter steel wire and covered with thin plastic sheet was mounted just above the motor housing of the sprayer **(Fig. 4)**. The contour of the shield followed nearly the spray trajectory.

The use of back spraying technique with the electrostatic sprayer was far more safe to the operator than frontal spraying with hydraulic-nozzle sprayer. In **Table 3**, no spray deposition was detected in the operator's head, nose, face or stomach with the electrostatic sprayer while spray deposition was greatest in these parts of the body with the hydraulic-nozzle sprayer.

Shielding of disc did not significantly ($P < 0.05$) reduce the spray deposition over the operator's body **(Table 4)**. In addition, spraying operation was made difficult with the use of shields, especially at wind velocities greater than 1.4 m/s, hence, it is not recommended.

Discussion

Back spraying could greatly reduce the operator's contamination with the drifting chemical spray. However, with this system, the operator cannot easily check problems such as clogging of the liquid lines and collision of the spinning discs with plants. A second person is necessary to help the operator in mounting the unit at his/her back. An Israel-made high voltage unit specifically designed for the electrostatic sprayer is estimated to cost US$22 each. Therefore, the cost of the sprayer is within the purchasing power of small farmers.

The performance of the prototype sprayer based on the preliminary tests was comparable in terms of weeding efficiency. This means that the prototype sprayer could be a suitable for the common hydraulic nozzle sprayer with additional benefits of safer spraying, less solvent requirement, and lighter to carry. The lower field capacity of the prototype could be partly attributed to the tendency of the operator to walk slowly as the spray from the disc was hardly visible.

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Spray Deposition with Conventional and Electrostatically-Charged Spraying in Citrus Trees

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Abstract

The aim of this study was to find an alternative to the hand gun (M_4) application using the conventional air-carrier sprayers (M_1, M_2, M_3) and electrostatic charged air-carrier sprayer (M_3*). Spray deposition on the leaves, losses under and between trees, and pest control efficiency were determined for four types of sprayers. Spray deposition on the upper and lower surface of leaves were determined quantitatively at three zones of the trees (top, middle, bottom) in all the directions, and outer canopy and inside canopy of trees from 24 locations on each tree, using fluorometric method and stardust tracer. The experiments were conducted in a Hamlin and W. Navel orange orchards. Pesticide losses were determined under and in space of betwen two successive trees. The biological efficiency for each sprayer was determined for controling Dialeurodes Citri (Ashmead) with white oil sprays.

It was determined that on the upper surface of leaves, stardust deposition was greater than the lower surface in both citrus variety. Outside deposition was found bigger than inside canopy deposition. Electrostatic charging increased the deposition, especially in W. Navel trees, but could not reduce the variability of deposition (CV) at the chosen zones on the tree in the vertical direction. Although air-carrier sprayers provided low relative deposition compared with the hand gun application, they have provided good biological efficiency similar to hand gun to control D. Citri. The highest losses were measured in treatment with hand gun.

Introduction

In Turkey, pesticide application in citrus orchards is performed manually with hand guns by using classical hydraulic sprayer. This system produces large droplets and requires the use of very high amounts of spray liquid to achieve the required coverage. Application rates used by hang guns vary from 3000 to 9000 ℓ/ha. This method not only involves an enormous utilization of active ingredients, but also a high energy consumption by machines (457 MJ/ha), and a high hand labour requirement (21.8 h/ha) (Juste et al., 1990).

The increasing concern of the general public about environmental pollution and food health and the rising cost of these pesticides necessitate on improvement of appliciation process in citrus pesticide. Analyzing the application cost of air-carrier spraying in Florida citrus, Whitney (1968) found that application costs are a function of spray volume, spraying speed, intergrove travel time, and daily service or other non-productive times. Citrus trees are evergreen, densely foliated, and with canopies often touching the ground may grow larger than 7.5 m in height and diameter (Salyani and McCoy). These tree characteristics create a difficult situation for spray application. In addition, target pests may be located outside or inside the canopy, on upper or lower surface of leaves, on fruit, or other parts of the tree (Carman, 1975). Therefore, a general purpose spray application may not provide the desired deposition and be effective in pest control.

In recent years, some citrus growers used locally local made air-carrier sprayer for treatment in Turkey. Some imported air-carrier sprayers, equipped with a static electric charging system, were demonstrated by their dealers. But we know that the provided efficiency with electrostatic spraying method depends on many factors, such as the properties of spray solution and plant varieties, microclimate conditions and charging method.

Many studies have been done to determine the efficiency of air-carrier sprayers (e.g., Randall, 1971; Reichard et al., 1979 and Fox et al., 1985). In an extensive three-year study of air carrier sprayer deposition characteristics, Randall (1971) concluded: (1) spray deposition was directly related with air-carrier velocity; (2) slower ground speeds provided the improved deposition; and (3) high air volume, rather than high air velocity at the sprayer exit resulted in greater air-carrier velocities within the target foliage.

Law and Cooper (1988) investigated depositional characteristics of charged and uncharged droplets applied by an orchard air-carrier sprayer. They found that depending on target location, electrostatically-charged spray achieved deposition increases ranging from 1.5 to 2.4 - fold over uncharged droplets from the same air-atomizing induction-charging nozzles, and the highest electrodeposition benefit was achieved on target backsides.

The specific objectives of this investigation were as follows;

(1) To determine active ingredient deposition, variability of deposition (CV), pesticide losses and biological efficiency on the tree of the used sprayers in citrus treatment

(2) To compare performances of the alternative equipment to the hand gun spraying method such as air-carrier sprayer and electrostatic charged air carrier sprayer etc.

Materials and Methods

Citrus Culture

The test was conducted in the orange plots with Hamlin and W. Navel varieties, 15 years of age, spacing of 7 × 7 m, located in the experimental station's citrus garden of the Agriculture Faculty of Çukurova University in Adana. The treated trees for deposition studies have a height of 5 to 5.5 m, a canopy diameter of about 5.5 m and leaf area index of 5.8 for Hamlin variety. These parameters for W. Navel were 3 to 3.5 m, 3.8 m and 2.5, respectively. Biological efficiency studies were conducted in different W. Navel trees which have a height of 4 to 4.5 m, a canopy diameter of about 4.2 m and leaf area index of 5.0.

Sprayers and Working Conditions

Sprayers used in this investigation are given codes of M_1 to M_4.

M_1 is a mounted type air-carrier sprayer with 12 cone type nozzles, which have a 1 mm orifice diameter, provided 20 160 m^3/h air capacity at 28 m/s at a pto speed of 540 rev/min with an axial fan, and also had a 400 L tank and a piston diaphragm pump.

M_2 is trailed type air-carrier sprayer with 10 cone type nozzles which have a 2.3 mm orifice diameter, provided 19 700 m^3/h air capacity at 45 m/s at a pto speed of 540 rev/min with an axial fan, and also had a 800 L tank and a piston pump.

M_3 is a trailed type air-carrier sprayer with 18 special vacuum nozzles, provided 13 240 m^3/h air capacity at 78 m/s at a pto speed of 540 rev/min with a radial fan, and also had a 1 000 L tank and a centrifugal pump. This sprayer also has an electrostatic charging system that works by induction method with 17 kV tension. Charging system may be used or not. Operation with electrostatic charging of M_3 is shown as the M_3*.

M_4 is a hydraulic sprayer with two hand guns with nozzles of 2.7 mm orifice diameter operated manually, and also had a 1 000 L tank with a piston pump.

All the air-carrier sprayers were trailed at the ground velocity of 3.5 km/h. The other working conditions are shown in Table 1.

Table 1. Working Conditions for Machines Used

Sprayer	Pressure (bar)	Droplet Sizes(1) (μm)		Application rate (L/ha)	
		VMD	NMD	Hamlin	W.Navel
M_1	35.0	212	112	1 031	1 031
M_2	7.0	237	110	617	617
M_3	1.4	132	62	2 147	2 147
M_4	40.0	380*	130*	4 080	3 060

(1): Droplet sizes were measured on the water sensitive paper.

(*): The height of turbulance chamber was 31 mm.

Orchard Works

Spray deposition and sampling procedure — Depositions on the upper and lower side of leaves were detected for each sprayer by a fluorescent tracer method using a fluorometer. Targets were sprayed with standard tracer substance dilution consisting of 0.2% stardust. It was assumed that the tracer residue distribution on the target would be analogous to the pesticide active ingredients in the spray. In investigation, filter papers having an area of 12.56 cm^2 (40 mm diameter) were used for the collection of spray droplets. Filter papers were attached to both upper and lower surface of leaves.

A randomized block experiment with three replications was conducted in both orange varieties in 1989. In each replication, sampling was conducted in two trees. Each tree was divided into three zones (top, middle, bottom) in height, in all directions (east, west, south, north) and both inside and outside of canopy **(Fig. 1)**. So, each tree was divided into 24 zones where droplets samples on the filter papers were taken from three leaves upper and lower side at each zone. After spraying the filter papers were collected separately and put in jars according to their position. Then 100 mℓ of distilled water was put into each jar in laboratory and the jars were shaken for 15 min. Then solution samples were taken from each jar

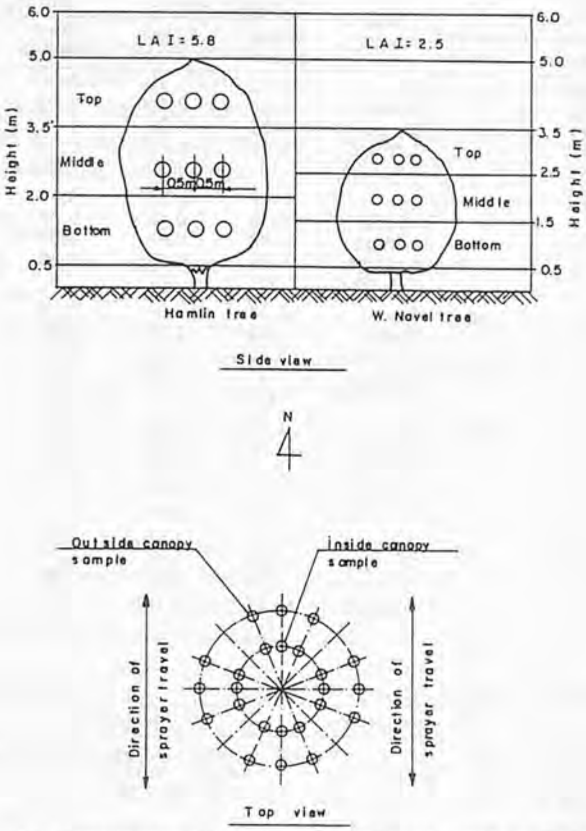

Fig. 1 Schematic view of the different zones and sample locations.

and analysed quantitatively using a Turner Model 111 filter fluorometer.

The relative deposition (RD) for all sprayers was calculated by considering stardust deposit determined on leaves and the applied stardust per cm^2 area of field surface to compare the sprayers due to each sprayer with different application rates. The following equations were used to calculate the relative deposition (Zeren and Moser, 1988).

$$RD = \frac{MS}{AS/LAI} \cdot 100$$

where,

RD = The relative deposition, (%)

AS = The ideal deposition on the unit surface calculated theoretically for each volume/ha, ($\mu g/cm^2$)

MS = The mean stardust deposition determined on filter papers at each zone by each sprayer, ($\mu g/cm^2$)

LAI = Leaf area index, (dimensionless)

Pesticide losses — For each sprayer on two successive trees on the same row, the losses caused by run-off and in space of two successive trees were quantified to compare the sprayers. To do this, four filter papers with an area of 122.5 cm^2 each were placed under each tree, and three papers in space of between two successive trees, regularly distributed over the ground.

Pest control — Tests of the biological efficiency were conducted in 1990. To determine the biological efficiency of each type of sprayer, *Dialeurodes Citri* (Ashmead) were chosen on W. Navel trees which have enough population. White oil sprays were applied by sprayers using a 1 400 cc white oil per 100 L of water. Sampling was done like the deposition estimate method, but using leaves directly. First count was done one day before the treatment and second count was done 3 days after treaetment. Then the biological efficiency was calculated using the Henderson Tilton Equation (Karman, 1971). The biological efficiency according to this equation is:

$$T = (1 - \frac{T_s \cdot C_e}{T_e \cdot C_s}) \cdot 100$$

where,

T = Biological efficiency (%)

T_s = Counting on the experiment plots (trees) after pesticide spraying

T_e = Counting on the experiment plots before spraying

C_s = Counting on the control plots at the same time which T_s counts were obtained

C_e = Counting on the control plots at the same time which T_e counts were obtained.

Results and Discussion

Spray Deposition

Table 2 shows the mean quantity and variability (CV) of stardust deposited on upper and lower surface of the leaves at the different zones according to the sprayers in Hamlin trees.

Because the use of sprayers have different application rates, each sprayer has provided different depositions on leaf surfaces (on filter paper). As shown in **Table 2,** the highest stardust deposition was provided on the upper surface of leaf by each sprayer and also deposition at the outside of canopy has been more than the inside of canopy in Hamlin trees. The highest deposition was obtained at the bottom zone of the trees while least deposition for all sprayers was determined at the top zone of trees.

The variability of deposition (CV) at the chosen zones was more

Table 2. Mean Values and Variability (%CV) of Stardust Deposition (μg/cm²) on Filter Papers on Hamlin Trees

Sprayer	Zones in Canopy	Outside canopy		Inside canopy	
		Upper surface	Lower surface	Upper surface	Lower surface
M_1	Top	0.33	0.26	0.27	0.21
	Middle	0.40	0.39	0.33	0.25
	Bottom	0.70	0.46	0.39	0.29
	Average	0.47	0.32	0.33	0.25
	CV, (%)	41	28	18	16
M_2	Top	0.25	0.24	0.22	0.19
	Middle	0.37	0.32	0.22	0.19
	Bottom	0.53	0.42	0.33	0.28
	Average	0.38	0.32	0.25	0.22
	CV, (%)	36	27	24	23
M_3	Top	1.30	0.39	0.26	0.14
	Middle	1.57	1.21	0.52	0.34
	Bottom	2.33	1.35	1.27	0.59
	Average	1.73	0.98	0.68	0.35
	CV, (%)	30	52	76	63
M_3*	Top	1.34	0.61	0.27	0.20
	Middle	1.54	1.65	0.60	0.45
	Bottom	2.53	2.06	1.18	0.96
	Average	1.80	1.44	0.68	0.53
	CV, (%)	35	51	67	72
M_4	Top	5.12	4.35	1.55	0.40
	Middle	6.11	3.72	1.67	0.60
	Bottom	7.08	2.95	2.23	0.87
	Average	6.10	3.67	1.81	0.62
	CV, (%)	16	19	20	37

Table 3. Mean Values and Variability (%CV) of Stardust Deposition (μg/cm²) on Filter Papers on Washington Navel Trees

Sprayer	Zones in Canopy	Outside canopy		Inside canopy	
		Upper surface	Lower surface	Upper surface	Lower surface
M_1	Top	0.42	0.31	0.21	0.19
	Middle	0.44	0.41	0.30	0.15
	Bottom	0.53	0.21	0.31	0.17
	Average	0.46	0.31	0.27	0.17
	CV, (%)	13	32	20	12
M_2	Top	0.49	0.70	0.30	0.22
	Middle	0.75	0.56	0.28	0.20
	Bottom	0.98	0.47	0.33	0.26
	Average	0.74	0.57	0.30	0.22
	CV, (%)	33	20	8	13
M_3	Top	1.07	1.04	0.36	0.23
	Middle	0.94	1.26	0.40	0.35
	Bottom	2.12	0.86	0.64	0.47
	Average	1.37	1.05	0.46	0.35
	CV, (%)	47	19	32	34
M_3*	Top	1.77	2.19	0.60	0.25
	Middle	2.01	2.45	0.65	0.59
	Bottom	2.87	1.56	1.06	0.79
	Average	2.21	2.06	0.77	0.54
	CV, (%)	26	22	33	50
M_4	Top	10.42	3.38	4.34	1.30
	Middle	12.81	3.18	3.57	2.56
	Bottom	13.28	4.66	4.05	1.97
	Average	12.17	3.74	3.98	1.94
	CV, (%)	13	21	10	32

important at the sprayer M_3 and its electrostatic application option (M_3*) when compared with the Sprayer M_1, M_2 and M_4. Electrostatic application (M_3*) of M_3 did not reduce the variability (%CV) in spite of the increasing deposition with electrostatic application at all the zones and surface of leaf in Hamlin trees (**Table 2**).

The vertical deposition variability of the tree depended primarily on sprayer air outlet shape. The height of Hamlin trees was about 6 m, but expansion of air jet of all air-carrier sprayers was between 2 and 3 m near the outside of canopy. Threfore, the bottom zone of the trees has been exposed to more depositions according to the top zone.

Table 3 shows the mean amounts and variability of stardust deposited on upper and lower surface of leaf at the different canopy sides and chosen zones in W. Navel trees.

Spray deposition on upper and lower surface of leaves in canopy sides of W. Navel trees have been like in the Hamlin trees. But the vertical variability of deposition on W. Navel trees has decreased if compared with the variability of deposition of Hamlin trees. Since the W. Navel trees are shorter than Hamlin trees, the variability in deposition has been low in the height compared to Hamlin trees. Electrostatic charging application of M_3 has increased the depositions on W. Navel trees and the variability of deposition with this application has also decreased to the level of other sprayers.

Table 4. Relative Deposition Achieved by Sprayers (Unit: percent)

Sprayer	Citrus variety	Outside canopy			Inside canopy			Total of averages
		Upper surface	Lower surface	Average	Upper surface	Lower surace	Average	
M_1	Hamlin	13	9	11.0	9	7	8.0	19.0
	W.Navel	7	4	5.5	3	2	2.5	8.0
M_2	Hamlin	18	15	16.5	12	10	11.0	27.5
	W.Navel	15	12	13.5	6	5	5.5	19.0
M_3	Hamlin	23	13	18.0	9	5	7.0	25.0
	W.Navel	8	6	7.0	3	2	2.5	9.5
M_3*	Hamlin	24	20	22.0	9	7	8.0	30.0
	W.Navel	13	12	12.5	5	3	4.0	16.5
M_4	Hamlin	43	26	34.5	13	5	9.0	43.5
	W.Navel	50	16	33.0	15	8	11.5	44.5

The relative depositions and their average achieved by sprayers in Hamlin and W. Navel trees are given in **Table 4**.

Relative deposition in both orange variety for all sprayers has been more at the outside canopy although air-carrier sprayers have an air-carrier power to penetrate the droplets into the inside canopy. On the other hand, spray penetration with hand gun has been very weak although the treatment was done like washing. The lowest relative deposition was achieved with sprayer M_1 in both citrus culture. Electrostatic charging of spray at sprayer M_3 has increased the total relative deposition, 20% in Hamlin and 73% in W. Navel trees. When the total relative depositions were compared, it was seen that the highest relative deposition was achieved with hand gun (M_4) in both citrus varieties. Total relative deposition achieved in Hamlin trees was higher than in W. Navel trees. We can say after this result; because of the leaf area index, the height of canopy diameter of Hamlin trees are bigger, pesticide losses decrease in this culture together with increasing the target area.

Pesticide Losses

Table 5 shows the average stardust losses produced by each sprayer under a tree and in space of between two successive trees.

The highest losses were sustained by sprayer M_4 (hand gun application) in both varieties. Sprayers M_1 and M_2 produced smaller losses due to their low application rate with vis-à-vis M_3 and M_4 which sustained higher losses although they provided higher relative deposition on the trees. Electrostatic application of sprayer M_3 reduced the losses in both citrus varieties. Decreases with electrostatic charging in losses were 11.6% for Hamlin and 24.5% for W. Navel under a tree, and these decreases were 14.7% for Hamlin and 13.8% for W. Navel in space of between two successive trees.

Pest Control

Table 6 shows the biological efficiency provided at the outside and inside canopy. The biological efficiency for each sprayer was greater at the outside canopy in which the relative deposition was already high for all sprayers **(Table 6)**. In controling *D. citri*, the highest biological efficiency provided with electrostatic application of M_3. Although sprayer M_1 has high application rate and active ingredient per tree with respect to M_2, sprayer M_2 provided higher efficiency than sprayer M_1. If the energy consumption, application rate and applying active ingredients to control *D. citri* are considered, it can be seen that sprayer M_2 was more effective.

Table 5. Stardust Losses Produced by Sprayers (Unit: $\mu g/cm^2$)

Sprayer	Losses under the trees		Losses in space of between trees	
	Hamlin	W.Navel	Hamlin	W.Navel
M_1	1.00	0.80	1.14	1.49
M_2	0.39	0.74	0.48	1.06
M_3	2.24	3.09	2.71	3.46
M_3*	1.98	2.33	2.31	2.98
M_4	8.89	10.91	3.45	6.34

Table 6. Biological Efficiency at Outside and Inside Canopy (Unit: percent)

Sprayer	Canopy side		Average	Changes in average $M_4 = 100$
	Outside	Inside		
M_1	51.6	46.8	49.2	71.0
M_2	57.2	53.9	55.5	80.1
M_3	72.0	45.7	58.8	85.0
M_3*	80.3	63.3	71.8	103.6
M_4	82.2	56.4	69.3	100.0

Conclusions

1. The mean deposition of stardust on upper surface of leaves was higher than on lower surface of leaves at the inside and outside zones in Hamlin and W. Navel trees.

2. The highest deposition with all sprayers was obtained at the bottom zone in the outside of canopy. The variability of deposition (%CV) in the height of tree was greater with sprayer M_3 and its electrostatic application. In general, air-carrier sprayers provided a greater variability of deposition than hand gun because of their heterogenous air carrying power distribution.

3. Relative depositions on the leaves with air carrier sprayers was lower than the hand gun application (M_4). Electrostatic charging of spray increased the relative deposition.

4. Pesticide losses occurred with hand gun was greater in both citrus variety to control the D. citri.

5. Two air carrier sprayers (M_2 and M_3) provided similar biological efficiency with hand gun application.

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Effective Treatment to Hasten Oil Palm Fruitlets Abscission Using Ethephon

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Abstract

In order to accelerate the loosening process of oil palm fruitlets, ethephon can be sprayed on the cut spikelets or brushed on the cut stalk of fresh fruit bunch (FFB) just after harvesting.

This study showed that the effect of sprayed ethephon (0-2 500 ppm) on the percentage of detached fruitlets was highly significant (p-value = 0.0001). The spraying of ethephon reduced the detachment force significantly (p-value = 0.0001) but did not influence the development of free fatty acid (p-value = 0.4345).

Even though this treatment was found effective for the spikelets, the spray of ethephon on bunch would loosen only the outer fruitlets.

This effect could be improved by brushing the compound on the cut stalk of fresh fruit bunch just after the harvesting. At 24 hours after applying 4 gram ethephon of 20-30% concentration, almost all of the fruitlets became easily detached from the bunch.

The result of this study would be useful in the design of the in-field stripping system of oil palm fruitlets.

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Introduction

The direct separation process of oil palm fruitlets from the bunch stalk is hindered by the high strength of the fruit-stem joint and the structure of fruitlets densely packed in a bunch. In order to facilitate their mechanical separation, the abscission of fruitlets must be accelerated so that they can be stripped as soon as possible in order to prevent deterioration of oil quality.

The present study identified effective treatment to hasten the loosening process of fruitlets from the cut spikelet and fresh fruit bunch. A commonly used growth regulator such as ethephon was used to accelerate the abscission of fruitlet. In aqueous animal fluids or plants, ethephon breaks down to produce ethylene.

Abeles (1973), Burgess (1985), and Kays (1991) reported that the abscission was induced by the ethylene which increased the secretion of enzymes such as cellulase, pectinase and hemicellulase into the middle lamella. This accelerates the degradation of binding agents between the cell walls. In certain abscission zones, ethylene may cause enlargement of cells located around the fracture line. This expansion develops stress leading to the rupture of tissue. As a pre-harvest treatment, ethephon could increase the fruit drop of apple (Noro et al., 1989; Pandita and Jindal, 1991), and reduce the fruit removal force of coffee (Crisosto et al., 1990). As a post-harvest treatment, it could hasten the ripening of banana (Salunkhe and Wu, 1974).

In the present study, ethephon was first applied on the cut spikelet as a post-harvest treatment. When the treatment was effective, its application was developed for the bunch composed of many spikelets. Bunch samples were selected from three ripeness levels, namely; unripe, just ripe, and ripe. The effect of treatment on the percentage of detached fruits and the strength of fruit-stem joint were measured at different periods. Subsequent investigation was carried out to determine the influence of the growth regulator on free fatty acid (FFA), the most critical quality parameter of palm oil.

Experimental Procedures

The first study was conducted to determine the effect of ripeness level, region, ethephon concentration, and their interaction on the loosening of fruitlets from the cut spikelets. The effect of ethephon and storage periods on the oil quality was also investigated.

The second study examined the effectiveness of ethephon application for the whole bunch.

Application of Ethephon on Spikelet

Percentage of detached fruitlets — In order to identify the factors which significantly affect the fruitlet abscission, 15-year old *tenera* oil palms were selected as source of fresh fruit bunches weighing 20-30 kg each. The bunches having loose fruitlets per kg bunch of less than 4, 4-8, and more than 8 were classified into unripe, just ripe, and ripe, respectively. Each bunch was divided into three equal regions, namely; basal, equatorial, and apical. After being cut from the stalk, the spikelets of about 1.5 kg weight were picked up randomly from each region and treated as an experimental unit. The units were then sprayed with 6 ml ethephon of different concentrations (0, 500, 1 000, 1 500, 2 000, 2 500 ppm). Once a particular treatment set was completed, the experimental units were then stored under the shade for 12, 24 and 36 h to permit the distribution of chemical in the spikelets and to complete the cell degradation at the abscission zone. Ethephon which was sprayed on the spikelet was expected to penetrate to the fruitlets through diffusion or imbibition.

A factorial experiment in strip-split plot design with five replications was used for this experiment. Three levels of spikelet ripeness and three bunch regions from which the samples were taken were assigned to the main and sub-plots according to a strip plot design. Then six ethephon concentrations were assigned to sub-sub plot randomly. The percentage of detached fruits was evaluated at the end of the storage period by comparing the number of fruits easily removed with the fingers to that of the total. In this separation, every fruit was picked manually with a minimum effort to ensure there was no damage.

Fruitlets detachment force — A study on the strength of the fruit-stem joint was conducted using unripe bunches. The spikelets from three different regions were sprayed with ethephon of 0 and 500 ppm. The latter was the minimum concentration which caused significantly different effect on the loosening of fruitlets from that of the untreated spikelet. In order to determine the effect of delay between ethephon application and pulling, tests were performed at 12 and 24 h after the treatment using the Instron Universal Testing Instrument equipped with an auxiliary device. It consisted of a gripper for holding the fruitlet at the required position and a steel wire to pull the stem.

The influence of detachment angle on the detachment force was examined by pulling the stem at 0° and 90° with respect to the long axis of fruitlet. The study was carried out using spikelets which were sprayed with 500 ppm ethephon and kept for 24 h.

Development of free fatty acid — This study was carried out to determine the effects of the degree of ripeness, application of ethephon, and storage period on the development of FFA. The FFA content is defined as the percentage of palmitic acid in the oil sample. It was determined according to the procedure suggested by Yeoh (1978) and PORIM (1986).

Application of Ethephon on Fresh Fruit Bunch

Percentage of detached fruitlets — In a preliminary study, ethephon with a concentration of 2 500 ppm was sprayed on unripe FFB. Even though the level of treatment was found very effective for the spikelets, it only loosened the outer fruitlets, even if the bunch was kept up to 24 h. This might be due to the slow diffusion of ethephon from the outer fruitlets into that of the inner layer. However, the brushing of 4 g ethephon (30%) on the cut stalk of about 25 kg bunch could loosen almost all of the fruitlets.

Such an application mode was then adopted in the subsequent experiment. In this investigation, under ripe bunches of 20-30 kg weight were applied with 4 g ethephon of different concentrations (0, 5, 10, 20, 30%) and kept in the field for different periods (12, 24, 36 h). The percentage of detached fruitlets under different treatments combinations was then determined from 1.5 kg of spikelets selected randomly from each region.

Fruitlets detachment force — The strength of fruit-stem joint was also determined for unripe bunch using a 3 × 2 factorial experiment in strip-plot design involving the region of fruitlets and the concentration of ethephon. *Tenera* oil palms were used as a source of samples. The bunch was applied with 4 g ethephon of 0 and 10% concentration. It was a minimum concentration producing the detached fruitlets which was significantly different from that of untreated bunch. After storing for 12 and 24 h, the bunches were chopped using a knife, and the spikelets were grouped according to their region (basal, equatorial, apical). A specimen consisting of a stalk and fruitlet was then prepared for the pulling test. The pulling test of each treatment was replicated five times using the experimental units selected from different bunches.

Results and Discussion

Loosening the Fruitlets from Spikelets

Factors affecting detached fruitlets— —The results of analysis of variance (ANOVA) for the percentage of detached fruit data of 12-h storage period indicated highly significant effects of ripeness (p-value = 0.0001), region (p-value = 0.0003), ethephon sprayed on spikelets (p-value = 0.0001), and region × ethephon interaction (p-value = 0.0306).

For the 24-h storage period, the strong significant effects were observed for ripeness (p-value = 0.0001), region (p-value = 0.0024), ethephon concentration (p-value = 0.0001). However, the effect of ripeness × ethephon interaction became highly significant (p-value = 0.0005). It was also found that the easy detachment of fruitlets was significantly influenced by the ripeness × region interaction at 5% level.

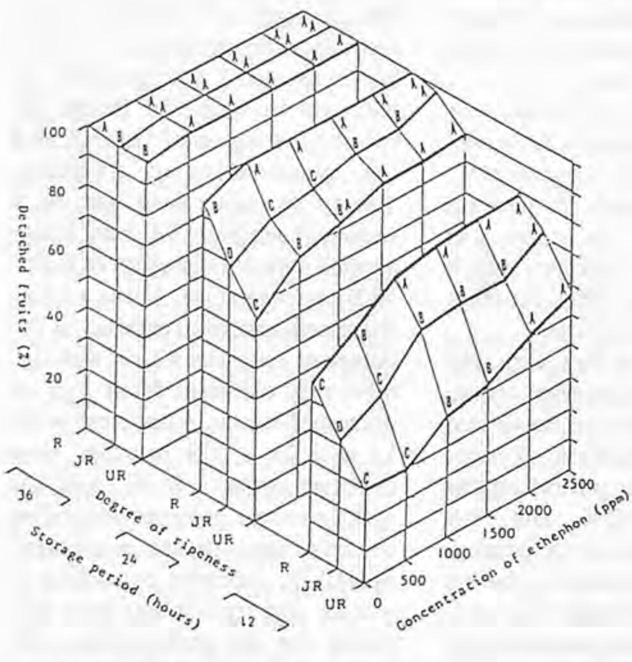
However, the results of Anova for the 36-h storage period data showed that strong significant effects on the percentage of detached fruitlets were detected for ethephon (p-value = 0.0001) and the ripeness × ethephon interaction (p-value = 0.0249).

In order to test the differences among all possible means affected by ethephon application, a multiple comparison procedure was carried out with Duncan's Multiple Range Test (DMRT). Comparison among means affected by ethephon is shown in **Fig. 1**.

For the 12-h storage period, the lowest to highest in detached fruitlets means for unripe, just ripe, and ripe spikelets were 30.06 - 53.66%, 42.90 - 72.83%, and 56.19 - 79.42%, respectively. For the 24-h period, these values were raised to 65.98 - 89.14%, 78.45 - 97.88%, and 93.60 - 100%, respectively. The lowest was observed on unsprayed spikelets, and the maximum was prevalent on the spikelets sprayed with 2500 ppm ethephon.

It was also obvious that increasing the ripeness level could raise the percentage of detached fruitlets. These effects were significant for the spikelets kept in the shade for up to 24 h. However, prolonging the storage time up to 36 h resulted in about 100% detached fruits for all degrees of ripeness, even with out any spraying.

Reduction of detachment force — The application of ethephon reduced the detachment force significantly (p-value = 0.0001). For the 12-h storage period, the force required to detach unsprayed spikelet was about 300 N, such a strong force can break the fruitlet at its middle instead of at the fruit-stem joint. However, a combination of the ethephon application and the storage period of 24 h reduced the pulling force to less



Note: • UR = under ripe spikelet
JR = just ripe spikelet
R = ripe spikelet

• At the same bold line, means followed the same letter are not significantly different by DMRT at 5% level.

Fig. 1 Comparison of means of detached fruitlets affected by ethephon sprayed on spikelet.

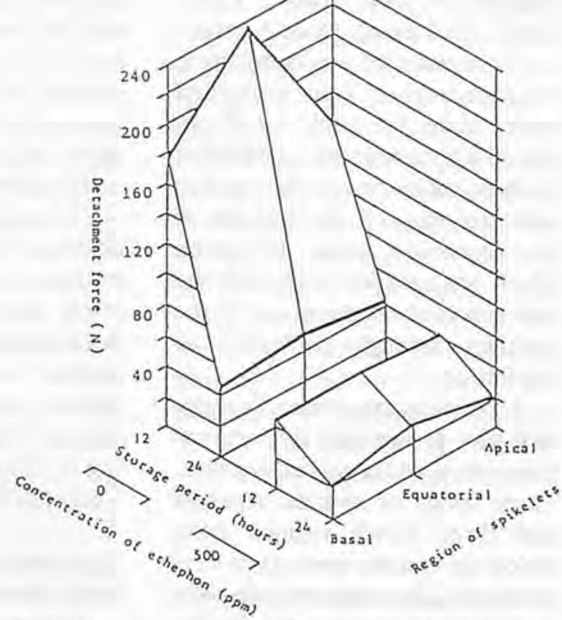
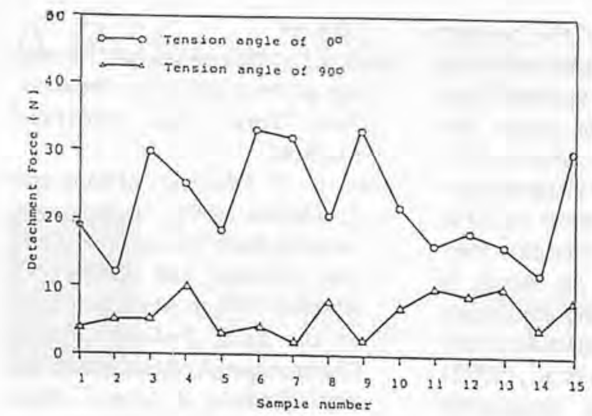
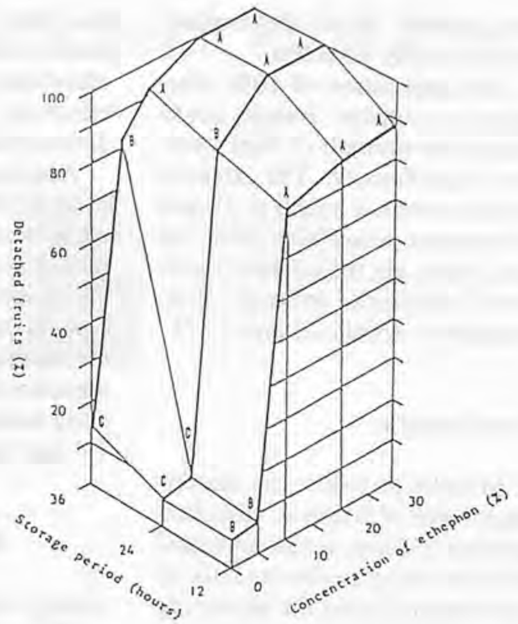


Fig. 2 Means of fruitlet detachment force in relation to storage period and ethephon sprayed on unripe spikelet (tension angle = 0°).



Note: Samples were selected from spikelets sprayed with 500 ppm ethephon and stored for 24 hours.

Fig. 3 Fruitlet detachment forces at tension angle of 0° and 90°.



Note: * At the same bold line, means followed by the same letter are not significantly different by DMRT at 5% level.

Fig. 4 Comparison of means of detached fruitlets affected by ethephon (brushed on cut stalk of unripe bunch).

than 20 N (**Fig. 2**). Most of the fruitlets even have become so loose that their strengths were difficult to measured.

A comparison among means of the detachment force at the tension angles of 0° and 90° is shown in **Fig. 3**. Increasing the tension angle to 90° reduced the detachment force to about 5 N which was only 25% of that at the angle of 0°. This separation process required less pulling force than that of 0° tension angle, where the failure in the tension occured over the entire stem section simultaneously.

Development of free fatty acid — The results of ANOVA for FFA show that the main effect of the degree of ripeness on the percentage of FFA was not significant (p-value = 0.6388). The averages of FFA produced by unripe, just ripe and ripe spikelets after being stored for 12 h were between 0.31% and 0.39%.

The ANOVA for FFA data measured at 12, 24, 36 h after spraying of 0-2 500 ppm ethephon showed that there was no significant effect of delay (p-value = 0.3864), ethephon concentration (p-value = 0.4345), and delay × ethephon interaction (p-value = 0.3599) on the development of FFA. The FFA produced by the treated fruitlets after storing for 12, 24, and 36 h were 0.54-0.69%, 0.47-0.64%, and 0.47-0.69%, respectively.

Fruitlet Abscission from Fresh Fruit Bunch

It was apparent that the application of 4 g ethephon of 30% concentration could loosen almost all of the fruitlets, especially for FFB weighing less than 30 kg. However, the percentage of detached fruitlets of the heavier bunch decreased with an increased bunch weight, especially for that from the apical region. As an illustration, a 33-kg FFB produced detached fruitlets of 100% at the basal, 93.9% at the equatorial, and 91.7% at the apical region, but that of 36 kg resulted in the detached fruitlet of 80.2% at the basal, 80.9% at the equatorial, and 68.7% at the apical region.

Further tests were conducted to study the effect of ethephon concentration on the percentage of detached fruitlets. The observations were made at 12, 24, and 36 h after the application. The results of the analysis of variance for the percentage of detached fruitlets data showed a high significant effect of ethephon application at 1% level. However, The effect of region was only significant at 12 h storage period.

To test the differences among detached fruitlet means using DMRT, the storage periods were fixed at 12, 24, and 36 h. Comparisons among that affected by ethephon concentration are shown in **Fig. 4**.

FFB which was not treated with ethephon would produce detached fruitlets of less than 20%, even after prolonging the storage of up to 36 h. The percentage of detached fruitlets could be raised by increasing the concentration of ethephon or storage period. At 24 h after being applied with ethephon of 20-30% concentration, almost all of the fruitlets become easily detached.

The application of 10% ethephon on unripe bunch could reduce the strength of fruit stem-joint significantly. The strength of the untreated bunch at 12 and 24 h storage period were about 300 and 160 N, but the treatment with 10% ethephon reduced their strength to within 25 and 20 N.

Conclusions

In order to reduce the detachment force of fruitlets, ethephon could be applied on the cut spikelet or brushing on the cut stalk of the bunch just after the harvesting operation.

This study shows that 24 h after spraying of 2 500 ppm ethephon at the rate of 4 mℓ/kg spikelet; the unripe, just ripe, and ripe materials produced detached fruitlets of 89.14%, 97.88%, and 100%, respectively.

The study also shows that the untreated unripe bunches produced detached fruitlets less than 20% even after prolonging the storage period up to 36 h. However, the bunch which was applied with 20% ethephon and stored for 24 h produced about 100% detached fruitlets. This treatment was found effective for most harvested bunches weighing less than 30 kg. For the heavier bunch, a higher concentration of ethephon should be applied. The treatment would not affect the development of free fatty acid.

Application of 2 500 ppm ethephon (4 mℓ/kg spikelet) or 30% compound (4 mg/bunch) may release ethylene in oil which is much lower than the minimum content causing observable effect on organism. Abeles et al., (1992) mentioned that the acceptable daily intake of ethylene is about 7.5 mg/kg body weight.

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ERRATA

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p.19, The author should read:
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p.20, column 1, AMDP of IRRI should read:
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A Rotary Tray System for a Solar Fruit Drier

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Abstract

A rotary tray system has been developed and tested for use in a solar tunnel drier. The system was designed to replace and overcome the main limitations which occurred with a previous system of stacked trays. The performance of the rotary tray system and the solar drier are discussed from the perspective of commercial producers of dried fruit for whom the technology is ultimately intended.

Introduction

In Australia, the production of dried fruit is an important industry with an annual (farm gate) value of production of $US 86 million, approximately 60% of this being export earnings. A number of products are produced, namely; dried currants, sultanas and raisins known as dried vine fruits, and dried apricots, pears, peaches and prunes, known as dried tree fruits.

The dried fruit is produced using a number of different methods. The bulk of the sultana, raisin and currants crops are air dried in long open sided racks, pears and apricots are sun dried on wooden trays, and "naturals" (sultanas dried without the use of a drying oil) and prunes are dried in dehydrators. In order to maintain its share of the world market, the industry is continuously searching for methods to improve final dried fruit quality and to reduce production costs.

The use of solar technology has often been suggested for the dried fruits industry both to reduce energy costs and to economically speed up drying which would be beneficial to final quality (Lambert et al., 1980; McBean, 1975; Szulmayer, 1973). Although the fruit is harvested in summertime at the time of high solar radiation, the season is unfortunately short which means that the technology must be low cost so that the investment may be recovered in a reasonable time period. Inexpensive polyethylene tunnels, as used by the greenhouse industry have been seen by several researchers as a possible way to use solar energy for drying (Ozisik et al., 1979; Lee et al., 1982; Trim and Ko, 1982; Fleming et al., 1987).

A tunnel drier **(Fig. 1)** has been built at Sunraysia Horticultural Centre in Irymple, Northern Victoria, to test the suitability of this technology initially to dry "naturals". This dried fruit was chosen for the trials because high prices are paid for the product to cover the extra production costs associated with dehydration, thus improving the financial viability of the solar system.

The first trials were carried out in 1989 and used stacked wire trays that could be wheeled in and out of the drier. The main limitation was found to be the uneven exposure to solar radiation which produced both uneven drying rates and colour changes in the fruit. The drier and these first trials have been fully described elsewhere (Fuller et al., 1989).

Fig. 1 Solar tunnel drier.

Acknowledgements: The assistance in this project from many other staff members of the Sunraysia Horticultural Centre is gratefully acknowledged. In particular, thanks go to Graham Wall who played a major part in the construction of the rotating tray system. The financial support of Renewable Energy Authority of Victoria and the Dried Fruits Research and Development Council is also gratefully acknowledged.

Rotary Tray System

Design Objectives

In an attempt to overcome the problem of uneven exposure to solar radiation, a rotating tray system was designed and tested in the 1990 and 1991 drying seasons. Other benefits of the system were seen to be an improved loading and unloading of the fruit, and a reduction in the temperature gradient within the drier due to the stirring action of the trays. As with the stacked tray system, an attempt was also made to increase the drier load ratio (kg of fruit per m^2 of drier floor area) closer to the high levels achieved in commercial tunnel dehydrators.

Rotating Tray System

The rotating device consisting of 15 wire mesh trays was constructed within the 6.1 m long by 4.3 m wide by 2.1 high polyethylene tunnel **(Fig. 2)**.

Each tray was made out of 20 mm square hollow section steel and covered with wire mesh. The trays were hung from a shaft, made from square section steel with a 16 mm diameter shaft welded into each end, by means of bush bearings and hanging rods. Wheel rims from 19 mm bore 160 diameter wheels were mounted at each end of the tray shaft and acted as rollers on the rails. The ends of each tray shaft were connected to two loops of double pitch 38 mm roller chain by means of special chain connectors.

Fig. 2 Rotating trays within solar tunnel drier.

The loops of the chain with the trays connected were placed on rails made out of 21 mm diameter 2.6 mm thick black steel tubing, supported by RHS steel. Four chain tensioners were placed at the corners of each loop of chain.

A 0.5 hp variable speed electric motor is used to rotate the trays. Chains and sprockets again with tensioners are used in the driving mechanism. Two wooden guides are also used to keep the chain on the sprockets.

The maximum speed of the motor was reduced from 1 700 rpm to approximately 28 rpm by a gearbox with a 60 : 1 reduction ratio. A control box was used to vary the speed of the motor between 0 and 28 rpm which allows each tray to make between 0 and 60 complete rotations around the tunnel/h. In general, the motor was controlled such that the rotational speed of the trays was 12/h. For operational convenience of the system, a switch was incorporated in the control box to reverse the direction of rotation.

Results

Exposure of Fruit to Solar Radiation

In the 1989 trials, the uneven drying rate and the variations in colour were primarily caused by the uneven exposure of the fruit on the stacked trays to solar radiation. From the top to the bottom trays, solar radiation attenuation was approximately 70%, 30%, 10% and 5%, respectively, of outside levels. At this time, the drier only had one layer of polyethylene glazing.

An additional layer of glazing was added to the drier prior to the 1990 trials in order to reduce heat losses. As a result, solar radiation inside the drier was also further reduced. Over a 6-day period, daily solar radiation levels of approximately 55% of outside were measured in the top centre of the drier.

Radiation levels on the rotating tray system were recorded by using a battery powered pyranometer placed on one of the trays. Solar radiation on the trays was reduced to 36% of outside levels because a tray travelling on the lower level would be shaded by the upper trays for half of the time.

Although on any individual tray, the uppermost grapes on the bunches dried faster and changed colour earlier than those underneath, drying rates and colour changes were overall much more even between trays, and were commercially acceptable.

Higher prices are paid for fruit which is even in colour. It was found that provided the fresh fruit placed in the drier was of good quality, the dried product always exceeded the base grade quality.

On- and-off Loading

One important criterion for a commercial operator will be the ease and, therefore, the speed at which the fruit may be loaded and unloaded in and out of the drier.

With the rotating tray system these operations can be carried out at one end of the drier with each tray being moved, stopped and then loaded/unloaded in turn.

Loading fruit was straight forward and took the same time as loading an equivalent area of a conventional drying rack. Initially some care has to be taken to load fruit evenly to avoid unbalancing each tray. Unloading fruit was simple because the trays could be tipped allowing the dried fruit to fall into boxes placed on the floor at the drier entrance.

Cleaning the wire trays was also found to be easy since each side could be brushed as the trays slowly rotated.

Load Ratio

In order to compete with commercial dehydrators, any solar drier must have an acceptable capacity or load ratio, i.e., mass of fresh fruit per unit of drier area.

A visit to a number of dehydrators in 1988 indicated that the load ratio varied between 100 and 200 kg/m^2 of overall drier area. This contrasts with approximately 40 kg/m^2 achievable with sun drying (Macrae, 1985).

The stacked tray system trialled in 1989 achieved a load ratio of 77 kg m^2 or between 39 and 77% of commercial load ratio levels.

The area occupied by the rotating tray system is 12 m^2 (6 m long by 2 m wide). There are 15 trays each with an area of 1.25 m^2 resulting in a capacity of approximately 750 kg of fresh fruit. Thus the load ratio is 62.5 kg m^{-2}.

However, this load ratio is further reduced because of the "dead" spaces in the drier either side of the machine which can only occupy the centre of the drier because of its height and the semi-circular shape of the structure. When these "dead" spaces are included, the load ratio falls to 30.5 kg m^{-2} or between 15 and 30% of commercial levels.

Temperature Gradient

In addition to the uneven exposure of fruit to solar radiation, the large temperature gradients that were generated within the tunnel drier in the 1989 trials also contributed to the uneven drying rates of the fruit in the stacked trays.

Temperature gradients of approximately 10°C were measured over the 2.5 m span between the floor and roof of the drier. It was hoped that the rotating tray system would adequately mix the air within the drier. As a safeguard, however, a household ceiling fan was also installed in the roof of the drier.

A series of trials were conducted to determine the effectiveness of the tray system and the stirring fan in reducing the temperature gradients, and the results of these trials are shown in **Table 1**.

Table 1. Effect of Rotating Trays and Stirring Fan on Temperature Gradient Inside Drier

Condition	Temperature Gradient
Trays not rotating Stirring fan off	8-10°C
Trays rotating Stirring fan off	approx. 6.5°C
Trays not rotating Stirring fan on	approx. 4.0°C
Trays rotating Stirring fan on	less than 2.0°C

Discussion

The discussion about the performance of this tunnel drier is based on the assumption that the ultimate objective is a design that would be acceptable to commercial producers. For growers, a number of factors will be of importance, and must compare favourably with commercial dehydrators. Ideally, the solar drier should:

(i) have low capital and operating costs;
(ii) have a high load ratio;
(iii) produce high quality fruit;
(iv) use commercially available technology;
(v) achieve uniform drying conditions;
(vi) have a high throughput of fruit; and
(vii) have a simple mechanical fruit handling system.

In relation to the above, it is believed that all but (ii) and (vii) compare very favourably with commercial systems.

Improving the Throughput

At present the solar drier does not have an auxiliary heater fitted to provide night-time drying. Small heaters installed are activated merely to prevent reabsorption of moisture and mould growth in the product.

Because little drying takes place at night, the thoughput is slow, each batch taking about three times as long as a commercial dehydrator even under good conditions.

In most cases, therefore, a solar drier used by a commercial operator would require an auxiliary heating system which should produce a throughput comparable with dehydrators. Energy consumption would obviously increase substantially from the minimal amount used at present. However, assuming that solar energy was able to provide approximately one-third of the energy requirements, savings would still be considerable.

Improving the Load Ratio

The low load ratio for the solar tunnel drier may present a considerable deterrent to most commercial producers of dried fruit. The exception may be dried apricot producers who still dry their fruit on wooden trays in the field.

The load ratio could be improved in two ways.

Firstly, the glazed structure could be designed to fit around the rotating machine which would avoid unused spaces. Unfortunately, this would negate two of the principal benefits of using standard greenhouse technology for the drier, namely; its commercial availability and low cost.

Secondly, the current rotating machine could be optimized to maximize its capacity. However, it is difficult to envisage a load ratio of greater than 80 kg m^{-2}, i.e., twice the sun drying rate being achieved. Alternatively, a complete redesign of the fruit holding system may be possible. Multiple layers of counter-rotating belts may be one possibility.

The alternative strategy is to abandon the hope of competing with the high load ratios of commercial dehydrators, and merely build a larger drier with an equivalent capacity to a commercial system. The low cost of film plastic tunnels should still produce a cost competitive installation.

Economic Assessment

It was estimated in 1990 that an eight-tonne (fresh) capacity commercial dehydrator would cost approximately $21 000. To have an identical output, a solar tunnel drier with a rotating tray system would need to cover an area of 153 m^2. It has been estimated that a 21 m × 7.3 m tunnel greenhouse, fully equipped, would cost in the order of $16 000, resulting in a 25% saving in capital cost. Replacement covers at a cost of $500 would be required every two to three years, but even with this expenditure savings would still result.

Fruit drying seasons are short, typically beginning in late December/early January for apricots and lasting through until early April for naturals. This means that the capital investment made in a dehydrator can only be recovered over three to four months each year, unless other crops for drying can be found.

The solar tunnel, on the other hand, could be used for horticultural purposes in the non-drying season. Either seedlings in boxes could be grown on the rotating trays, or this system could be removed giving full access to the structure. The idea of adapting solar driers for horticultural use in the non drying season has been suggested by other researchers (Muller et al., 1989). Multiple use of the technology in this way will undoubtedly improve the economic viability of the system.

Conclusions

A solar tunnel drier has been described with a novel rotating tray system. This system offers the advantages of even drying, and easy-on and off-loading compared with the stacked trays. It also appears to be economically competitive with conventional dehydrators although this requires confirmation from a more detailed analysis.

In the past, apricot growers have attempted to overcome the disadvantages of placing and recovering trays out on the ground with a motor driven wire rope system from which the trays were suspended (McBean, 1976).

The rotating tray system or an adaptation of it is similar in concept, and the trays have been merely enclosed with conventional technology from the horticultural industry. Hence the possibility of acceptance of the technology is increased. One innovative grower in the region has already adapted a double layer quonset greenhouse for finish drying his sultanas (Anon, 1988). This grower won a prize at the local field day for his innovation.

The main problem identified with the system are the low throughput of dried product and loading ratio. It is believed that further development work could find accpetable solutions to these problems.

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Mechanization Inputs to Agriculture in Oman

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Abstract

Development of agriculture in the Sultanate of Oman has received a major thrust since 1970. From this time agricultural mechanization inputs have been considered as essential for agricultural production. A review of mechanization activities indicate that the area has featured in the development plans of the Sultanate. Mechanical services in the form of tractor ploughing have been provided to farmers. Extensive spraying of crops has been carried out by the government. Tractors, water pumps and spraying machines have been distributed to farmers under subsidized and soft loan scheme. Processing of dates at factory level has been carried out. Agricultural machinery industry is developing. Agricultural mechanization graduates have been produced by the country's Sultan Qaboos University. Mechanization research and development have been initiated. In this paper it is suggested that a mechanization policy be formulated and mechanization activities and information coordinated.

Introduction

Major advances have taken place in the development of agriculture in the Sultanate of Oman since 1970 when the era of modernization started. Since that time the Ministry of Agriculture and Fisheries has operated a vigorous exension service through the Department of Agricultural Affairs. Through the extension service farmers have been made more aware of the use of inputs such as fertilizers, improved seeds, new varieties of crops and machinery in agriculture.

Before 1970, there were only two experimental farms, one at Sohar and another at Nizwa. In 1972 a research station was opened at Rumais near Barka. Another research station had been

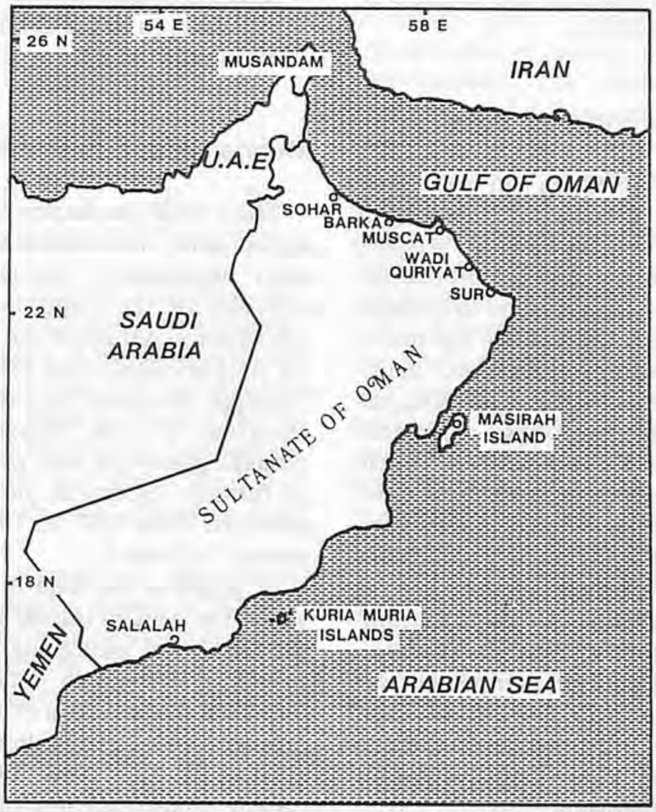

Fig. 1 Map of Sultanate of Oman.

established at Wadi Qurayat (Fig. 1). Through the activities of the research stations farmers started to become oriented towards modern techniques in agriculture and to deal scientifically with their production activities. The adoption of modern methods of production has required mechanization research.

In 1990, Sultan Qaboos University, College of Agriculture, produced its first graduates of agriculture. Among the graduates were those who have specialized in Agricultural Mechanization to provide manpower in this area.

There appears to be a modest start regarding mechanization inputs to agricultural development in Oman. Mechanization is important in the modernization of agriculture and such related fields as food and agro-industries and fisheries. This paper, therefore, reviews mechanization activities in agriculture and makes suggestions for enhancing the effectiveness of mechanization.

Mechanization Inputs

Mechanization can be defined as the process of interjecting power and machinery between man and materials in a production system. Mechanization as it relates to agriculture requires the study, manufacture, utilization, maintenance and repair of all tools, implements, machines, equipment and structures which will enable the farmer to raise the productivity of human labour economically.

To help raise the productivity of the farmer, inputs such as mechanization extension, machinery manufacture, sales and service, mechanization manpower development and mechanization research and development must be provided. These inputs will result in the following:

1. *Michanization extension*: Provision of machines and mechanical services and advice on mechanization operations.
2. *Machinery manufacture, sales and service*: Production of developed machinery, provision of required machinery for purchase and provision of repair and maintenance service.
3. *Mechanization manpower development*: Provision of education and training in the professional and technological categories at various levels. These include higher level manpower at the officer grades such as Professional Engineers, Agricultural Mechanization Specialists and Irrigation Specialists, middle level manpower such as technicians and superintendents and lower level manpower such as operators and artisans.
4. *Mechanization research and development*: Carrying out machine design and testing and machinery demand assessment, selection and performance evaluation.

Mechanization Extension

Since 1970 the importance of agricultural mechanization has been emphasized through the activities of the Department of Agricultural Affairs of the Ministry of Agriculture and Fisheries. Through the Intensive Extension Program of the Department ploughing services were provided to farmers. Hours of ploughing provided from 1977 to 1990 are shown in **Table 1**.

A graph of the data in **Fig. 2** shows the trend of tractor services in terms of ploughing hours provided. The graph indicates a decline in the provision of services around 1986. The decline coincides with the 1986 oil price decline. This indicates that less funds were available for investment in tractors. During the period when ploughing services had been provided cultivated land area had doubled, that is, from about 30 000 ha to 56 000 ha.

The Intensive Extension Program coordinates with the Department of Agro-Industries in the spread of mechanical pollination of dates. Date palms are one of the most important crops in the Sultanate. The pollination process is critical as the size of dates production depends mainly upon its success. Due to shortage of labour for efficient pollination, the Ministry has introduced simple mechanical pollinators for the purpose. The activity carried out in collaboration with the Date Palm Development Project partly funded by the Food and Agriculture Organization of the United Nations has been designed to encourage farmers to use the machinery in order to avoid labour problems which they will otherwise face.

Aerial spraying of 16 000 to 21 000 ha (38 000 to 50 000 feddans) of land under date palm is carried our every year by specialized technical teams of the Department of Agricultural Affairs for the control of insect pests. During 1985 and 1986 the Ministry carried out a project for the spraying of coconut trees against insect pests in the south of Oman. Coconut trees numbering 163 000 were sprayed. In order to strengthen the

Table 1. Tractor Services Provided to Farmers

Year	No. of Tractor Ploughing Hours
1977	31 742
1978	50 527
1979	58 465
1980	67 541
1981	79 597
1982	84 373
1983	80 613
1984	69 795
1985	56 375
1986	50 206
1987	61 342
1988	87 225
1989	81 444
1990	73 527

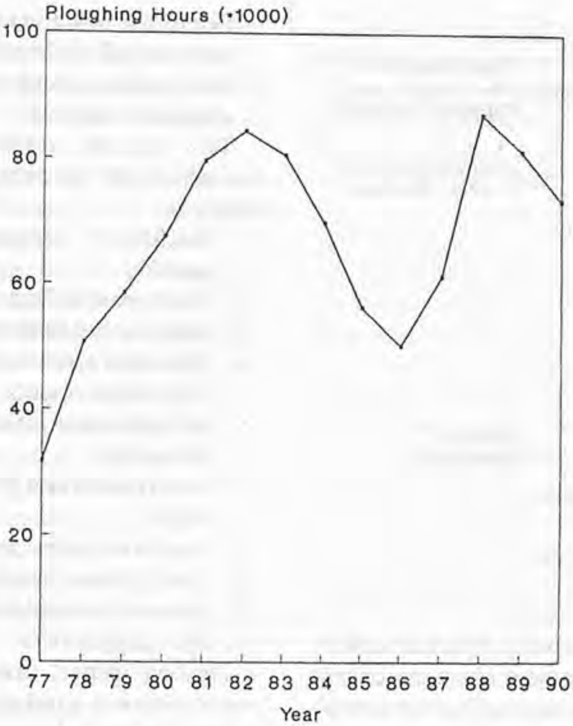

Fig. 2 Tractor ploughing hours, Oman.

Table 2. Distribution and Value of Agricultural Equipment Distributed to Farmers

Type of Equipment	1983	1984	1985	1986	1987	1988	1989	1990
	Value (000) Rials Omani*							
Tractors								
Value	110	90	123	24	18	93	86	216
Number	153	141	131	10	4	23	22	49
Water pumps								
Value	239	669	387	187	74	114	203	152
Number	744	1 872	982	420	74	124	220	148
Spraying machines								
Value	159	139	141	89	194	82	159	30
Number	2 066	2 118	2 000	816	1 200	670	1 740	230

*1 Rial Omani = US$2.58 (1990).

control of agricultural diseases affecting different kinds of crops the Ministry distributes different kinds of insecticides spraying machines to farmers. Soft term loans subsidized by the Government are advanced for the purchase of sprayers.

Machinery provided by the Government since the start of agricultural mechanization in 1970 include tractors, tillage implements, planters, threshers, harvesters and sprinkler irrigation equipment. The Oman Bank for Agriculture and Fisheries has a loan program for farmers, especially big holders who are interested in acquiring tractors. The number of tractors, water pumps and spraying machines distributed to farmers from 1983 to 1990 are given in **Table 2**. From 1988 to 1990 the distribution was carried out under the Oman Bank for Agriculture and Fisheries loan scheme.

The Ministry of Agriculture and Fisheries needs to have a department which would deal with mechanization extension matters such as advice on proper selection, operation and servicing of agricultural machinery. The department can also provide governmental machinery repair and maintenance services to farmers.

Since early 1970 the Ministry of Agriculture and Fisheries has paid attention to agro-industrialization of crops which achieve surplus in production. Processing plants have, therefore, been set up and mechanization of processing operations have been undertaken. Dates processing plants were set up and opened in 1975 at Nizwa and Rustaq. To obtain good results in the two factories, fumigation units and steam boilers were installed and operated in 1986.

Machinery Manufacture, Sales and Service

The manufacture of agricultural machinery in the Sultanate is at the initial stage. Among the few machinery pieces manufactured are water pumps, engine radiators and batteries. The Ministry of Agriculture and Fisheries is currently sponsoring, through the Date Palm Improvement Project, the manufacture of date palm pollinators and mechanical platforms for date palm pollination and harvesting operations.

The Sultanate relies heavily on imported agricultural machinery. The importation of agricultural machinery from 1977 to 1983 amounted to U.S.$ 77.032 million. **Table 3** shows the yearly importation. Beside 1982 the figures indicate an increasing trend of agricultural machinery for the period.

The types of agricultural machinery imported include tractors, rotovators, ploughs, har-

Table 3. Imported Agricultural Machinery

Year	1977	1978	1979	1980	1981	1982	1983
Value in US$'000	10 684	10 946	11 198	11 440	11 728	9 223	11 813

Table 4. Tractor Makes Imported and Dealer Agencies

Tractor Make (Power Level kW)	Country of Origin	Dealer	Other Equipment
Massey Ferguson (33)	United Kingdom	Zawawi Trading Co. P.O. Box 58, Muscat Tel. 562077	Irrigation Equipment
John Deere (46-61)	U.S.A.	Oman Technical Agencies LLC P.O. Box 423, Muscat Tel. 696106	Irrigation Equipment Pruning Machines
Ford (57-78) Kubota	U.S.A. Japan	Bahwan Engineering Co. LLC P.O. Box 6168, Ruwi Tel. 561377	
Case	U.S.A.	Industrial Trading Co. Ltd. P.O. Box 508, Muscat Tel. 701166	
Deutz	Germany	SATA LLC P.O. Box 814 Muscat Tel. 592544	
Iseki	Japan	Muscat (Overseas) LLC P.O. Box 3488, Ruwi Tel. 703844	Sprayers Generators
Yanmar	Japan	Oman Marketing and Services Co. P.O. Box 5734, Ruwi Tel. 560391	
Garden tractors	China Japan	Ahmed & Moh'd Al-Khonji Co. Tel. 795973	

rows, cultivators, planters, sprayers, threshers, harvesters, water pumps and sprinklers. Various makes of tractors whose dealers operate in Oman are imported from various countries. **Table 4** lists tractor makes, countries of origin and sales and service agents. Some power levels and other equipment carried by dealers are also indicated. The dealers provide repair and maintenance services for their machinery.

Mechanization Manpower Development

As machines, mechanical systems, engineering structures and mechanized processing operations are applied to agriculture, properly educated and trained mechanization manpower is required for effective operation. Oman has technical institutions which can provide the base for the training of tractor and machinery operators, mechanics and technicians.

For the development of higher level personnel who are to be engaged in mechanization, the Sultan Qaboos University, College of Agriculture, has a Department of Agricultural Mechanization. The Department has a major role of training mechanization specialists to obtain scientific and applied engineering knowledge and skills to use in various agricultural mechanization operations. A specialized degree program in Agricultural Mechanization in the University began in 1986. In 1990 a first set of seven students graduated from the program. A second set of eight students graduated in 1991.

The program of the Department aims at contributing to effective mechanization in the workplace through the training of mechanization specialists with the capability to:

1. Apply any or all of the applied engineering principles to the solution of problems in agricultural production and processing;
2. Undertake economic selection, utilization, maintenance and repair of equipment in agricultural production and post harvest operations;
3. Improve and retain the quality of farm and fisheries products through appropriate process operations;
4. Conserve and permit more efficient use of natural resources such as soil and water; and
5. Undertake agricultural mechanization research.

The trained mechanization specialists are to work, among others in:

1. Machinery companies and agencies
2. Fertilizer and feed companies
3. Banking institutions
4. Extension service and government departments
5. Soil and water resource establishments
6. Government and private large farms
7. Food and agro-industries
8. Educational institutions
9. Research establishments
10. Self-employment

Among other places where mechanization graduates of the Sultan Qaboos University have been placed so far, are the Ministry of Agriculture and Fisheries (extension, irrigation, agricultural statistics and research), Diwan of Royal Court Farm, private companies and the university.

Mechanization Research and Development

Lack of water, hard soils and excessive heat are among the factors which render the cultivation of crops and the raising of animals in Oman difficult. The introduction of mechanization in agriculture backed by adequate research can assist greatly in overcoming production problems. Recognizing this, the Government has set up research centers and made provision in its five-year development plans for mechanization and engineering research.

A Central Research Station was established at Rumais in 1972 and at Wadi Qurayat during 1973. During 1983 a separate station was set up in Salalah and entrusted with research responsibilities in the southern region. The three centers present different agricultural situations in separate environments and results obtained will complement each other.

Mechanization and related research objectives in the centers are as follows:

1. Adoption of new technology in mechanization in agriculture and use of farm machinery for higher productivity;
2. Preservation of crop products;
3. Evaluation of aerial spraying of date palms; and
4. Irrigation and water engineering research.

Under the current five-year development plan (1991-1995) an Agricultural Mechanization research unit in Rumais is to be set up. The establishment of the unit should promote machinery need assessment, selection, performance evaluation and developmental research.

Research priority areas of the Department of Agricultural Mechanization of the Sultan Qaboos University, College of Agriculture include:

1. Mechanization of field operations;
2. Irrigation systems and soil and water conservation;
3. Processing and solar drying of agricultural products and fish; and
4. Environmental control for agricultural structures.

For effective selection and proper management of machinery for field operations, research studies should include:

1. Determination of soil resistance for obtaining machine draft and power requirements and
2. Development of machinery use, service and cost data.

Mechanization Problems and Prospects

The major agricultural regions in the Sultanate, namely; Batinah to the North, Sharqiya to the north-east, Dhahira to the north-west, the interior and the south around Salalah, (**Fig. 1**), have different environmental conditions such as climate, soil, vegetation and topography. The north has desert conditions while the south has considerable vegetation. Various field crops are grown and different animals are raised. Among the crops, date palms dominate taking 38.9% of cultivated area of about 56 000 ha. With the availability of suitable water, another 40 000 ha can be cropped. Other fruit crops grown include citrus, mangoes, bananas, coconut and papaya. The important vegetable crops grown are tomatoes, potato, pepper, eggplant, onion, garlic, cabbage, cauliflower, carrot, lettuce, beetroot, spinach, watermelon, cucumber, pumpkin and okra. Cereal, legume and fodder crops include alfalfa, sorghum, wheat and peas. Animals raised include sheep, goat, cattle, camel and poultry.

There is a large number of small scattered farms with complex cropping patterns and intercropping practised in the country. In the Batinah region which accounts for at least 50% of cultivated land in the Sultanate, there are 10 000 to 15 000 privately owned small holdings.

The harsh and varied environmental condition, small scatterd farms with complex cropping patterns and intercropping and the importation of a variety of machinery makes can present mechanization problems associated with the following:

1. Availability of appropriate machinery for various crops and types of mechanized operations;
2. Adequate utilization of machinery in an economic size operation to generate enough income to cover machinery costs; and
3. Adequate provision of facilities and manpower for the repair, maintenance and overall management of machinery.

The fourth five-year development plan (1991-1995) of the government has provisions which have implications for mechanization and, therefore, present mechanization prospects. The provisions include:

1. Improvement of irrigation system and centrally controlled water distribution system;
2. Establishment of Agricultural Mechanization Research Unit at Rumais Research Center;
3. Establishment and development of agricultural technology information units at extension centers;
4. Technology transfer to farmers through subsidizing agricultural mechanization;
5. Date palm development program which will ensure increased production of high quality dates;
6. Meat processing and milk collection and processing;
7. Establishment of agro-industry complex for processing dates, lime and tomatoes;
8. Establishment of units for vinegar processing;
9. Establishment of coconut processing plant; and
10. Improvement of Oman Bank for Agriculture and Fisheries capabilities (Loans Scheme for Machinery Purchases).

Suggestions on Mechanization Strategy

Mechanization in agriculture has been included in the development plans of the Sultanate. Farm machinery provides a strong link between agriculture, industrial and service sectors of the economy. It will be desirable to establish a focal point such as a national committee on mechanization in agriculture and related fields to formulate a mechanization policy and coordinate agricultural mechanization planning and support in the context of the overall development plans. The policy formulated and the activities to be coordinated should take note of the following:

1. Standardization of machinery imported into the country;
2. Performance evaluation under Omani conditions of new machinery being imported;
3. Choice of appropriate form and level of mechanization;
4. Mechanization of livestock production and processing; and
5. Mechanization of post harvest processes for converting field crops and fish products into processed forms.

The body established can coordinate information on:

1. Mechanical services, maintenance and repair services by Government, quasi-Government and private organizations;
2. Machinery inventory and demand for farm mechanization from machinery users;
3. Manufacture and supply of machinery by manufacturers and dealers;
4. Manpower needs of employers and training by institutions; and
5. Research, machine design, development and testing by the University and research institutions.

Conclusion

A review of the history of mechanization in agriculture in the Sultanate of Oman indicates that:

1. Since 1970 agricultural mechanization has featured in the development plans of the Sultanate;
2. Mechanical services in the form of tractor ploughing has been provided to farmers;
3. Spraying of crops, both aerial and ground, to control insect pests has been carried out;
4. Tractors, water pumps and spraying machines have been distributed to farmers under subsidized and soft term loan scheme;
5. Processing of dates is carried out at two factories at Nizwa and Rustaq;
6. Agricultural machinery industry is developing;
7. Agricultural mechanization manpower training at the tertiary level is undertaken at the Sultan Qaboos University; and
8. Mechanization research and development have been initiated.

It is suggested that a mechanization policy with particular reference to agriculture and related fields be formulated and mechanization activities and information be coordinated.

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Steps in Mechanizing Agriculture in Rural Areas

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Abstract

The traditional hoe and cutlass continue to be the main and often, only implements for all farming operations in rural Cameroon. Attempts to mechanize agriculture at the rural level, where the bulk of the food is produced, often fail. This paper suggests alternative approaches to implementing mechanization programs based on the concept of appropriate technology. A non-functional equation for mechanization is proposed and a recommended flow chart for implementing a mechanization program is given.
Keywords: mechanization, appropriate technology, Cameroon, Tropical Agriculture.

Introduction

Agriculture in Cameroon constitutes the bulk of the economic activity and involves a large proportion of the working population. Seventy percent of the working population make a living from agriculture which accounts for 40% of the Gross Domestic Product and 70% of the country's total export (Neba, 1987; World Bank, 1988, 1989). Cameroon's agriculture is highly traditional and concentrated in the rural areas with a diversity of farming methods. The intensive use of hand tools, especially the hoe and cutlass **(Table 1, Fig. 1)**, limits farm sizes **(Table 2)** and food production can no longer meet the demands of an ever growing population.

Table 1. Farm Tools Used by Farmers

Tool	% of Farmers Using Tools	Ranked 1st as Important
Hoe	99.7	49.0
Cutlass	99.0	91.6
Axe	61.7	77.4
Tractor	3.1	—
Spray	54.2	—
Digger	80.0	—
Truck	50.2	75.0

Source: Atayi and Knispscheer, 1980; Endeley, 1987.

Table 2. Land Size Under Cultivation

Hectares	% of Farmers N = 285
Don't Know	90.0
<1.4	3.1
1.5-3.4	4.8
3.5-5.4	0.7
5.5-7.4	—
>7.5	1.4

Source: Endeley, 1987.

A regional survey of farmers in the Eastern and South-western Provinces of the country revealed that more than 55% of the farmers had no formal classroom education (Atayi and Knipscheer, 1980; Endeley, 1987) and more than 60% were under 45 years of age **(Table 3)**. Unfortunately the population of these "food producers" is fast decreasing; so too is food production (World Bank, 1989). The following partially explain the observed trends. First, the proportion of young farmers replacing the aging ones is insignificant. This may be blamed on the prevailing educational system that has led young people to believe that farming is not an occupation for anyone with some degree of literacy **(Fig. 2)**. Farming is generally viewed as a *way of life* for the illiterate and a last resort for literate job seekers.

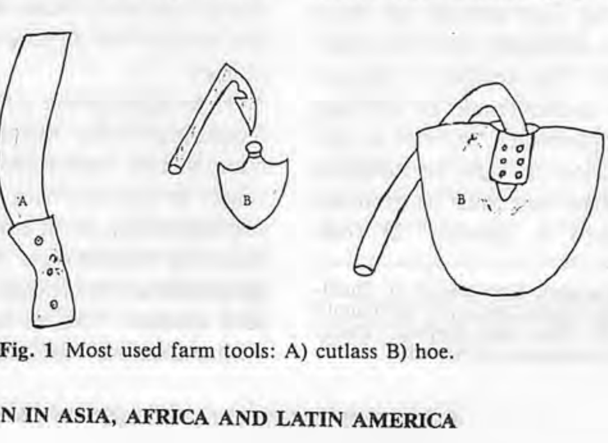

Fig. 1 Most used farm tools: A) cutlass B) hoe.

Table 3. Frequency Distribution of Farmers by Age

Age Group (Years)	% Endeley, 1987	% Atayi, 1980	% Average
<25	12.9	12.0	12.5
25-34	29.1	21.8	25.5
35-44	25.9	23.2	24.6
45-54	22.7	23.6	23.2
55-64	8.0	14.9	11.5
>64	1.4	4.6	3.0
Mean Age	38.0	42.0	40.0
% <45 years	67.9	57.0	62.6
No. Surveyed	286	216	251

Second, the rudimentary agricultural tools and implements do not allow for mass food production to meet the growing population. The fewer the number of people involved in farming, the more there is the need to shift away from traditional farming systems to mechanizing agriculture at the village/rural level.

The importance of mechanization as a necessary factor to increase production has been outlined with a number of recommended actions.* The question is no longer whether mechanization is an option, but what approach should be taken to increase the farm area of the small-scale farmer? This paper, discusses some approaches, based on the concept of appropriate technology.

Agricultural Mechanization and Appropriate Technology

Esmay et al., (1972) define agricultural mechanization as *the scientific application of mechanical aids for increased production, processing and storage of food with less drudgery and increased efficiency*. This implies: 1) the use and the improvement of existing tools/implements, as well as the introduction of new or adapted ones, whose cost must be minimal to ensure a profit; 2) that

*International Conference of Small-Scale Farm Mechanization in the Humid Tropics of West and Central Africa. Yaounde, Cameroon; June 1980.

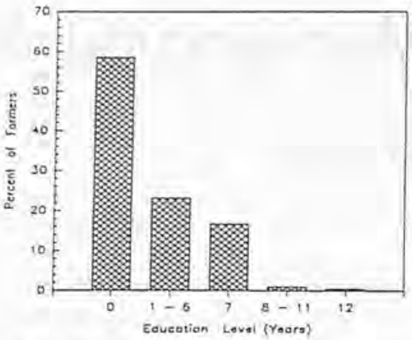

Fig. 2 Education level of farmers.

mechanization embraces the manufacture, distribution and operation of all types of tools, implements, machines and equipment for farm activities (FAO, 1981); and 3) that the power source (human, mechanical or animal), among other factors, be the key in determining the technological level of mechanization in any given locality.

While increasing output may be the goal in mechanization, the conservation of resources, soil and energy should be a priority.

Technology has been defined in agriculture as the *application of technical knowledge involving the use of specific inputs of a biological, chemical or mechanical nature in a specific pattern* (Bodenstedt, 1977). Bodenstedt's definition suggests that the term does not only refer to machinery and technical skills, but goes beyond to include training programs, organizations, management systems, research and development, etc. As such, technology should serve as a link between needs and the means to satisfy those needs thus, the concept of appropriate technology.

How appropriate is appropriate technology? An average Cameroon farmer sees a combine harvester or tractor, with its level of sophistication, as an inappropriate form of technology. Also inappropriate are the rudimentary hoe and cutlass. This is not to say "intermediate technology" is appropriate technology; there is a wide range of technologies between the combine harvester and the hoe that are considered intermediate, but each suits a particular need.

The Agency for International Development states two criteria for determining the appropriateness of a given technology: it must be 1) relevant to the social goals of the area and 2) be applicable to the particular area. To be applicable the following questions must be answered. Are the necessary human resources available to apply the technology? How suitable is the technology to the situation? What is the level of sophistication? Is it affordable and profitable? Is the technology compatible with the cultural and social norms of the area? A case is cited where sheep farmers deserted gasoline-driven engine sheep shearing equipment, because the noise from the engine prevented the visiting between families that, traditionally, was the highlight of the annual shearing period (FAO, 1981).

A small degree of inappropriateness is enough to have a damaging effect on a project. Farmers, for example, may abandon new double-handed oxen-drawn ploughs and return to old single-handed ones, because the new ones require re-training of the oxen and a second person to guide the oxen. Animal traction may be a recommended form of technology for farming, but the type of animal selected will determine its appropriateness. For example, horse farming will be inappropriate in a community where farming is done by women and a horse-woman association is a cultural taboo. In areas where the animal is a cultural food, farmers will likely eat the animal and return to their traditional methods, rather than keep it as a power source. Religious practices in an area may render power supply from a sacred river an inappropriate form of technology. Appropriate technology can, therefore, be considered suitable means or efforts to provide objects and or ideas for human sustenance and comfort. Furthermore, it should deal with the efforts to introduce, develop and apply useful knowledge to meet the needs of the community, taking note of the social, economic, cultural, religious and political settings of that community.

By applying the concept of appropriate technology to mechanization, some general conclusions can be drawn. The type of power available should be the basis for selecting the type of technology and level of mechanization. The selected technology should be simple to use, low cost, expandable and easy to adapt. It should, if possible, be developed at the site of its intended use. Most experts agree that the basic determination of appropriateness occurs in the field, where the potential technology is tested in its intended area of use. Unfortunately, this has not always been the case. Modern technology, most often, has simply been transplanted to farmers with little or no basic training.

The Steps

Successful implementation of a mechanization program in any rural area requires an effort by policy makers, institutions and extension agents to introduce new mechanical techniques, upgrade, expand and adapt existing ones; train and educate the farmers. It would also mean an effort on the farmers' part to be willing to accept new and adapted technologies and be prepared to risk the unknown.

Meaningful Mechanization

When mechanical aids are introduced, they should fulfil the social, cultural, employment and productive needs of the local farmers. Mechanization policies also should take into consideration energy conservation. This implies the development and introduction of low energy farming systems and an efficient use of agricultural machinery/implements. Where animal traction is an option, care should be taken not to link it with livestock raising where neither of them is likely to develop satisfactorily (Pingali et al., 1988). Only when apropriate, should motorization and tractorization be introduced.

Introduced technologies should be such that they rely heavily on local resources and (if possible) make use of recycled materials; there should be a real need for them. In the past, mechanized equipment has been introduced not because there was a "need" for it but because it was the offspring of a political idealogy. Suitably designed hand/animal operated machines and tools should be the norm in those areas where energy and finance are constraints.

Foreign or advanced technologies, when considered, should be adapted rather than transplanted except in those cases where it's been proven beyond reasonable doubt that the transplanted technology will be successful. In such cases questions such as: 1) are there trained technicians and operators?; 2) are the spare parts available?; and/or can they be made or replaced locally? must be answered in the affirmative. Transferred technolojgy from industrialized countries has proved ineffective (Khan et al., 1987) in non-industrialized countries. Tractors in Cameroon, for example, have not been of value to the rural farmers. Of 287 farmers surveyed in the South-West Province, only 3.1% indicated they had used a tractor (**Table 1**). Even in CENEEMA**, a graveyard of unserviceable and unrepairable, rusty machines is a common sight. Some have not been used since their importation. Apart from the fact that these imported technologies are usually in the hands of a few, they benefit only a few and tend to create a social difference.

While the use of agricultural equipment and adequate machinery are imperative, to agricultural mechanization, their importation should be minimized and the domestic production of agricultural equipment (from local material) encouraged and fully supported.

Create an Agricultural Mechanization Organizations (AMO)

A well defined policy of mechanization is the key to success for any implemented program. AMO's main objective should be to decide the level of mechanization that is appropriate for different localities. These decisions should be based on the rural structure, and the farming systems that are unique to different parts of the country: villages, districts, divisions and provinces. Consideration should be given to the climatic and geographical conditions of these regions. For example, the type of mechanization selected for an area with <250 mm of annual rainfall will be different from the type selected for one with >2 000 mm of annual rainfall. Farmers in the forest region will have a different mechanization scheme from those in the grasslands.

Mechanization policies developed by AMO should define the limits of mechanization and select optimum techniques. These will serve as guidelines for agricultural engineers and technicians in

**National Center for Studies and Experimentation in Agricultural Mechanization, Cameroon.

designing agricultural tools/implements and systems that are appropriate. Designed tools/implements should be such that they allow for horizontal mechanization, i.e., the use of agricultural equipment in areas not originally meant for them, e.g., the use of trained oxen for farming in the transportation of food crops in off-farming seasons, or the use of an ox cart for spreading manure.

AMO should strive to work in close cooperation with local manufacturers and mechanization centers and farmers. The best results can be obtained when there is a close cooperation between agronomists, soil and social scientists as well as technical specialists. Training and research programs should target the grass roots (village), since this is the level most affected and where direct coordination and program implementation takes place.

Create an Extension Service Team

The team should comprise of people from all agricultural disciplines and cultural anthropologists/rural sociologists. The team should monitor and advise farmers and personnel involved in training programs; advise and encourage farmers to use new and available technologies; evaluate different farming systems, and plan and carry out trial demonstration programs. Such demonstrations should be on a section of the farmer's farm for comparison by the farmer who will have the sole decision whether or not to accept the introduced technology or farming method.

Table 4. Extension Visits to Farmers

Number of Visits	% of Farmers Visited
None	80.9
1-2	15.4
3-4	2.7
5-6	—
7-8	—
>9	1.0

Source: Atayi and Knispscheer, 1980.

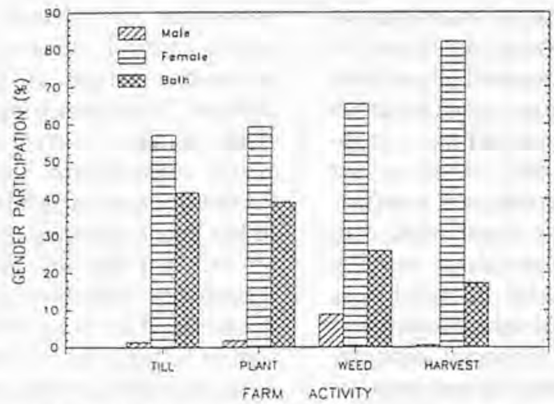

Fig. 3 Gender participation in agricultural activities.

For an effective extension program, the number of farmers per extension agent should be minimal. This has been one of the major weaknesses of many failed agricultural programs in Cameroon. In a case study of the WADA Project in North-West Cameroon, Muzinger (1982) reported 1 extension worker for every 60 farmers. Eighty-one percent of the farmers Endeley (1982) surveyed in the South-West Province had never been visited by an extension agent (**Table 4**).

In those communities where farming is done mostly by women (**Fig. 3**), more women should be a part of the extension team as a woman-woman interaction on farm issues is more cordial than a man-woman interaction. In some cases, women farmers have often questioned the rationale of young men "teaching" them farming techniques learned in the class room. Extension agents working with groups of farmers may improve extension effectiveness.

Planning

Although mechanization may need policy support, it should not, in any given locality, be the offspring of a political idealogy. It should be the result of a coordinated effort that can take the form: $P_{mech} = f(X_1, X_2, \ldots X_n)$, where f is an environmental (ecological, cultural or geographical) function that determines the effect of inputs from the X variables; $X_1 \ldots X_n$ would be the farmers, villagers, scientists, engineers, technicians, anthropologist/sociologists, and economists, and P_{mech} is the resulting mechanization program to be implemented. Government planners may be a variable if there is a need for government support through policy or programs, i.e., a subsidized purchase scheme. Notice that all the variables in the above equation have the same power. This means that none of the variables in the planning process should dominate the other.

The farmers or villagers must never be left out of the planning process for they, and only they, best understand their environment that constitutes the farming systems (FAO, 1981). The farmers or villagers involved choose and determine what mechanical inputs are best for them depending on their economic strength, cultural, social and religious practices; scientists and engineers handle the technical part of the program; economists, the economic aspect; and anthropologists/sociologists advise on the social and cultural implications of the program.

Teaching of Agricultural Sciences

The introduction of agricultural

sciences in the primary and secondary schools is of significant importance. In Cameroon the present school curriculum does not allow for an early exposure to agricultural careers. The result is that students enter state agricultural institutions, not because of any pre-knowledge or interest in an agricultural career, but because they are attracted by the money they start receiving the day they are admitted. It is not surprising to find that secondary school graduates do not know the difference among a soil scientist, entomologist, agronomist, etc. Those who find their way to these state institutions, through public examinations, graduate not as agricultural workers or farmers, but as agricultural "masters."

Mechanizing with the System

If the slope and size of a land is such that it does not permit the use of machinery, no attempt should be made to introduce machinery. Moreover, the soil's response to an implement should be tested before its use on that soil type. Mixed cropping, a long-time cultural practice, should not be replaced by mono-cropping. Farmers find many advantages in mixed cropping: crops are intensified on the most fertile lands, pests are minimized, farming operations are not repeated and movement between farms is minimized. Instead, the mechanization program selected or designed should be that which allows for this cultural practice. In most farms corn (*Zea maize*), beans (*Phaseolus sp*), groundnuts (*Arachis hypogea*), etc. are intercropped. It should be a challenge for the agricultural engineer to produce, say, a hand-driven seed drill that plants all three crops in three alternate rows.

In some localities farmers practice societal farming: a group of women, usually 5, work consecutively on each farm, then the cycle is repeated. In those areas where finance for mechanization is a constraint, such a farming practice should be encouraged or introduced. It is advantageous because these farmers can jointly own agricultural equipment, which they otherwise might not have owned as individuals.

Blacksmiths are still a useful element in the rural society and should be incorporated into the mechanization process. One way of doing this is through an Association of Agricultural Blacksmiths and Engineers (AABE). AABE's priority should be the local design and production of agricultural equipment. Blacksmiths and artisans should be trained and widely dispersed and integrated in the rural communities. Well trained blacksmiths cannot only repair equipment but are capable of making new and modern equipment or tools, from local materials, if given the design (**Fig. 4**). As an encouragement, annual or bi-annual exhibitions/contests should be organized where prizes are awarded to deserving teams or individuals based on what has been produced, and its applicability and effectiveness in accomplishing tasks. Most important, retraining programs for technicians should be an essential goal of the association, as the demands for farming technologies will change.

Recommended Procedure

Studies have attributed some program failures to manpower coordination between research organizations and mechanization projects and an absence of an integrated policy between farm mechanization and agro-industrialization. The accusing finger has always been pointed to the administration. What is the procedure for implementing any mechanization program? **Fig. 5** is a recommended procedure for implementing a mechanization program. Two key steps in the figure must be noted: 1) "select mechanization program" and 2) 'select test ground." It is recommended that the participation and input of the community in selecting the program should not be neglected, as the selected program should be based on the needs of the people in that region. The test ground should be the area of intended program implementation. The village, the smallest population unit in the Province is recommended for this purpose. Butler (1970) points out that although the village is the lowest level in any given establishment, it is the highest level charged with direct responsibility for the coordination and allocation of local resources and the implementation of policy.

Fig. 4 An example of tools blacksmiths can make.

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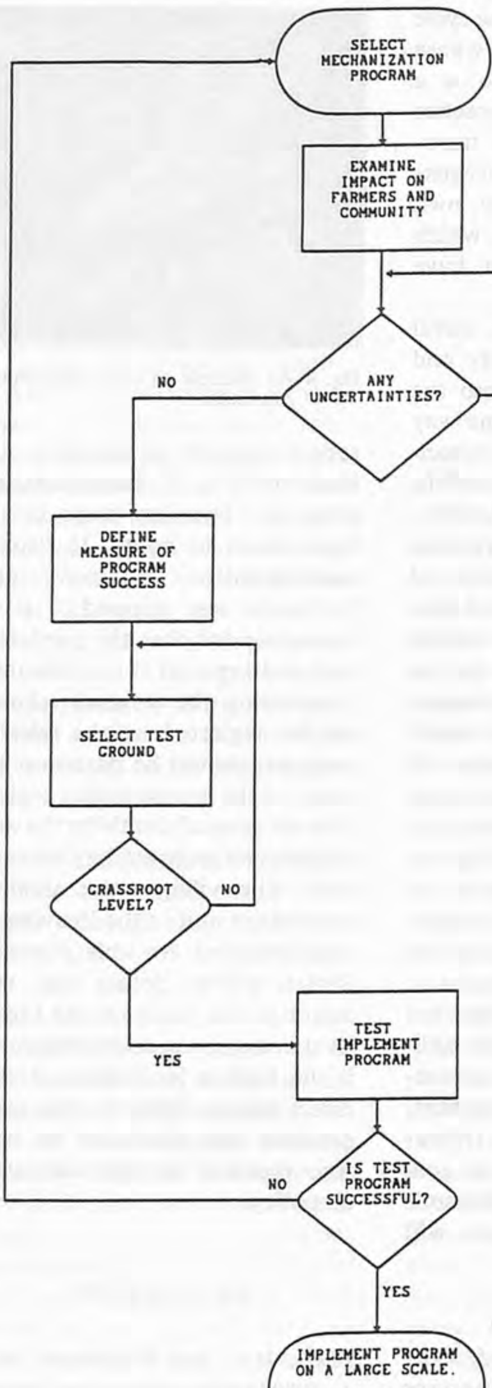

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An Economic Analysis of Tractorization of Indian Agriculture: A Case Study in Punjab State

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Abstract

The Punjab State of India has witnessed rapid mechanization of agriculture during last two decades. The number of tractors has gone up to 265 000 in 1990-91 while the cultivated area remained at about 4 200 thousand ha. This study, based on a sample of 113 tractor-owner farmers, shows that on average, power availability per hectare was 3.61 hp on the sample farms. The crop-wise use of tractor showed that paddy and wheat were the main crops in the crop-mix farming which accounted for 33.96% and 39.60% of the total use on tractors owning farms, respectively. Seedbed preparation, sowing of seed, marketing of products, threshing and puddling were the important farm operations for which tractors were being used.

The fixed costs and variable costs of tractor use were Rs. 95.66/h. These costs were almost at par with the custom-hiring rates prevalent in the State. About 37.20% of the tractors were being used for less than 300 h/annum and their use could be considered uneconomical. An equal number was operated between 400-1 000 h/annum and was regarded within economically safe range while the remaining about 25% were operating just at the break- even point. This calls for promoting more custom-hiring of tractors, shift in the cropping patterns as well as modifications in the credit policy for purchase of tractors.

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Introduction

The Punjab State has exhibited an exemplary growth in the agricultural sector since mid-sixties. The introduction of high-yielding varieties, increased use of fertilizers and expansion of irrigation facilities accompanied by progressive mechanization of farm operations are largely responsible for this breakthrough.

The introduction of farm machinery has played a significant role in increasing agricultural production due to timely performance of crucial farm operrations. Rapid rise in the cost of purchased inputs such as seed, fertilizers, insecticides, etc. has necessitated precision in placement and application of these inputs. The use of appropriate farm machinery has helped in achieving this objective. Substitution of mechanical power in lieu of manual and animal labour became essential in view of the fast rising wages of human labour and escalation in the maintenance cost of animals. Druggery of human labour and the upkeep of animals has also been an important consideration in mechanization. The scale of economies could be better taken advantage of by the introduction of farm machinery resulting in efficient management of large-sized farms. Various social and psychological considerations have also motivated the farmers to mechanize their farms.

The partial budget analysis to determine the profitability between animal and tractor operations has become irrelevent owing to the remote possibility of reverting from tractor to animal farming. Thus the non-economic forces seem to have overweighed the economic rationale for such an investment in agriculture. Perhaps it could be the reason due to which the number of tractors has rapidly increased even though the average farm size has declined.

Literature Review

Many studies were carried out in the past to analyze the impact of tractorization on the profitability of Indian farms (Dhawan and Mittal 1991). Until the mid-70s, increased farm productivity was highly associated with the use of tractors (Singh and Kahlon, 1976). But recent studies have shown that over-investment in tractors in relation to farm size was making the machinery less economical in Punjab agriculture (Mander 1987, Singh and Sidhu 1990). Despite these trends, the number of tractors has increased steadily, i.e., from 4 935 in 1960-61 to 125 050 in 1980-81 and 265 000 in 1990-91 (Stat. Abstracts, Punjab). However, the cultivated and cropped area did not keep pace with this increase. Consequently, the intensity of tractors per unit area increased at a fast rate. Such a huge investment in farming along with dwindling profits from this occupation have put the farm economy at the cross-road necessitating to reconsider the utilization pattern of existing tractors for various operations and examine the cost-return aspects of tractor use. Hence the present study was carried out in 1991-92 with the following specific objectives:

1. To examine the availability of tractor power and utilization of tractors for different operations;
2. To study the cost and returns from the investment in tractors; and
3. To suggest measures to rationalize further investment in farm machinery in the Punjab.

Methods and Materials

The study was carried out in six districts of Punjab, namely; Gurdaspur, Amritsar, Kapurthala, Sangrur, Bathinda and Ferozepur. From each district one block* was selected at random. From each of the selected blocks, 20-25 farmers owning tractors were selected covering 3-4 villages that represented different farming conditions of that district. Thus, in all 113 farmers were selected for an in-depth analysis of the problems.

The information regarding the farm size, cropping pattern, availability and use of tractor power for various farm and non-farm operations, purchase price of the tractor and of allied equipment, repair and maintenance, fuel and oil cost, insurance and taxes, wages of operator, value of shed, etc. were collected from the selected farmers.

For the purpose of analysis, the costs were divided into fixed cost and variable cost. The fixed cost included depreciation of tractor and allied equipment and shed for parking the tractor and interest on the capital. The variable cost included cost of diesel, mobil oil, insurance and taxes, wages of driver and repair and replacement.

Results and Discussion

An analysis of resource availability of sample farmers shows that more than two-thirds of the farmers owned operational holdings ranging between 4 and 12 ha. Only 7 farmers operated two ha and one farmer had three tractors. Twenty eight of the 113 farmers operated an area of more than 12 ha. On the other hand, 6.20% farmers had operational holdings of less than 4 ha and were underutilizing the tractors on their own farms.

The largest number of tractors in use were of the 35 hp. Only 18.03% of the farmers owned 25 hp tractors and about 32% owned tractors of 40 hp or more. It was thus, pertinent to analyze the power availability per unit operated area. It was seen that 61.06% farmers in Punjab had 2.5 to 5.0 hp/ha. Still higher horse power was available on 30.09% of the farms. The overall average available power was 3.61 hp/ha for the sample farms.

Tractor Utilization Pattern

Table 1 shows that tractors were used about 84.59% of the time performing various farm operations. About 8.01% of tractor utilization was for custom hire and 7.40% for social activities such as attending festivals, marriages, religious functions, etc. The use for social functions was considered unproductive but in some cases it was unavoidable because other modes of transport were more cumbersome though generally less expensive.

A split up of tractor use on tractor users' own farms for various crops is presented in **Fig. 1**. Tractor utilization for different crops and crop pattern shows that paddy and wheat were the dominant crops covering 24.24 and 36.36% of the total cropped area on the sample farms. Further, these crops accounted for 33.96 and 39.60% of the total use of tractors on users' own farms, respectively **(Table 2)**. Sugarcane, cotton and vegetable crops accounted for over 5% of total tractor use each. Oilseed crops which occupied over 10% of the total cultivated area utilized the tractors only for about 2.23% of the total use. Thus the cropping pattern of a farm was one of the significant factors which influence the rationale of investment in tractors and

Table 1. Utilization Pattern of Tractors on Sample Farms in Punjab, 1991-92

Type of use	Annual use (h)	Percent of total
On own farm	332.20	84.59
Custom-hiring	31.49	8.01
Social work	29.10	7.40

*A block is an administrative entity which comprises about 100 villages and covers area of about 30 000 ha.

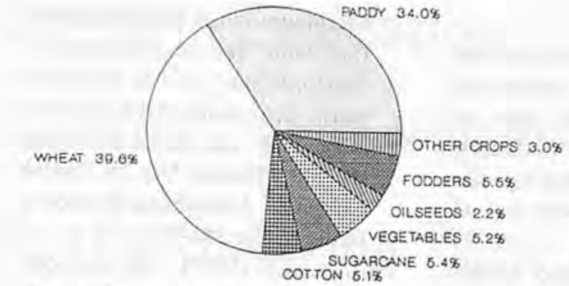

Fig. 1 Percent tractor utilization for different crops, Punjab.

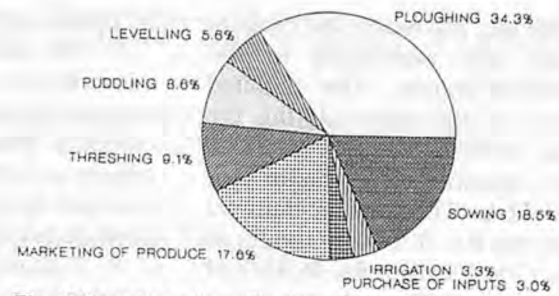

Fig. 2 Operation-wise utilization of tractors, Punjab.

farm machinery.

The tasks performed by tractors are listed in **Table 3**. Seedbed preparation was the single most important operation which accounted for 113.99 h of annual tractor use. This was about 34.27% of the total hours of use on the farm. Sowing and planting accounted for 18.46% of the total use **(Fig. 2)**. Next in importance were the marketing of produce, puddling of the soil, and threshing of crops. Tractors were also used for land levelling, smoothing (planking), for lift irrigation, and for transport of farm yard manure and various farm inputs.

Table 2. Tractor Use on Sample Farms for Different Crops Grown in Punjab, 1991-92

Crop	Average area under the crop (ha)	Percent of total cropped area	Annual use (ha)	Percent of total use on own farm
Paddy	4.8	24.24	112.95	33.96
Wheat	7.2	36.36	131.73	39.60
Sugarcane	1.0	5.05	17.93	5.39
Cotton	1.0	5.05	16.85	5.07
Summer oilseeds	0.6	3.03	1.49	0.45
Winter oilseeds	1.4	7.07	5.92	1.78
Summer fodders	0.8	4.04	8.09	2.43
Winter fodders	0.8	4.04	10.38	3.12
Vegetables	0.6	3.03	17.26	5.19
Other crops	1.6	8.03	10.03	3.01
Total	19.8	100.00	332.63	100.00

Table 3. Operation-wise Utilization of Tractors on Sample Farms, Punjab, 1991-92

Operation	Average annual use of tractor (h)	Percent of total use on own farm
Ploughing	113.99	34.27
Levelling	18.66	5.61
Sowing	61.40	18.46
Puddling	28.75	8.64
Lifting water for irrigation	10.98	3.30
Threshing	30.42	9.14
Marketing of produce	58.43	17.57
Purchase of inputs & transport of FYM	10.00	3.01
Total	332.63	100.00

Table 4. Average Cost of Operation of Tractors on Sample Farms in Punjab, 1991-92

Items	Annual cost/tractor	Annual cost/ha	Cost/h
Fixed cost			
Depreciation of tractor, allied implements and shed	6 470.64	620.50	16.46
Interest on investment @ 15% p.a.	12 885.80	1 235.70	32.77
Total fixed cost	19 366.44	1 856.20	49.23
Operational cost			
Diesel	10 204.36	978.40	25.95
Mobile oil	799.70	76.68	2.03
Insurance & Taxes	366.64	36.15	0.93
Wages of driver	1 688.20	149.40	3.96
Repair and replacement	5 330.66	511.12	13.56
Total variable cost	18 289.56	1 750.75	46.13
Total cost	37 646.00	3 606.95	95.66

One rupee (Rs.) = 0.04 US$.

Cost of Operation

The cost of operation was influenced by tractor make, horse power, type of operation, etc. The annual use of tractors in hours was a crucial factor in determining the cost/h. Tractor operation involved a number of components of costs. Farmers were conscious of some but not all of them. The average fixed and operational costs were almost at par with each other and jointly accounted for Rs. 37 646.00/tractor/annum. The average investment of a tractor and its equipment at current market price was estimated at Rs. 79 626.87 with an expected life span of 13.11 years. The average cost of a tractor shed was estimated at Rs. 6 277.46 with a life span of 15.83 years. Thus, the depreciation of machinery and shed together accounted for Rs. 6 470.64/annum/tractor. The other major item of fixed cost was the interest which was at 15% annum, the prevailing rate. These fixed costs amounted to Rs. 19 356.44/annum or Rs. 1 856.20/ha or Rs. 49.23/h of tractor use.

The cost of diesel was the most important among the operational cost items which amounted to Rs. 10 204.36/annum or Rs. 25.95/h of use. Next in importance was the repair and replacement cost amounting to Rs. 5 330.66/annum. The imputed wage of the driver during the year 1991-92 was Rs. 1 588.20 for operating the tractor for 393.22 h. The total operational cost was Rs. 18 289.56/annum or Rs. 1 750.75/ha or Rs. 46.43/h of tractor use. Thus, the total cost per hour was Rs. 95.66, which was lamost at par with the average custom-hiring rates prevailing in the State.

Conclusions and Recommendations

1. The tractor, on the average, in the Punjab State did not find adequate work for its rational use and was hardly covering the costs. Inspite of it, an important economic consideration for the purchase of tractor by the farmers was that of the ever-increasing price of tractors. Even by considering the 10% rise in the price of an average tractor, 37.20% of the tractors were operating at less than 300 h/annum which was regarded as an uneconomical use. About 24.79% tractors worked for 300-400 h/annum which was a break-even point. The remaining 38.01% tractors worked between 400 to 1 000 h/annum and could be considered to have found adequate work. Thus, the number of tractors in Punjab was rather large which did not find adequate work and, consequently, pushed the cost of operation high.

2. The area-wise distribution of tractors in the State called for rationalization on the basis of cropping patterns of different regions such that the existing tractors and machinery could be utilized during the year.

3. Custom-hiring also needed to be encouraged instead of keeping the tractors idle due to social prestige.

4. Further investment in tractors in certain areas and on specific farms out to be curtailed by way of suitable credit policy. For example, small farmers having remote possibilities of hiring out tractors should not be advanced loans for this purpose.

5. The Punjab agriculture is heading towards specialization in paddy-wheat rotation which has led to overuse of machinery only for specific farm operations in a limited time during the year. Diversification of agriculture not only in terms of crops but also with respect to crop varieties with non-overlapping growing periods will hold the key for better utilization of tractors and farm machinery.

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■■

On-farm Evaluation of Low External Input Weed Control Technologies in Direct Seeded Rice in the Savanna Zone of West Africa

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Abstract

Hand weeding is the major labor activity in direct seeded upland and rainfed lowland rice in West Africa and delayed weeding results in significant yield reduction. The objective of this study was to develop and test weed control options that would allow earlier, more rapid and repeated weeding in direct seeded rice. These options included: (1) row seeding rice with animal-drawn and manual seeders; (2) mechanical inter-row cultivation with animal-drawn equipment; and (3) in-row weed control with herbicides or by hand-pulling. The animal-drawn *SuperEco* seeder proved superior to the hand-pulled *Casamance* seeder. Cultivating at 21 and 42 days after seeding (DAS) with the animal-drawn *Occidental* hoe controlled inter-row weeds, yielding 1.3 t/ha in upland rice and 3.2 t/ha in rainfed lowland rice with no control of in-row weeds. In-row weeds were effectively controlled by broadcasting oxadiazon (RONSTAR) at 0.75 kg a.i./ha 1 DAS or by banding thiobencarb and propanil (TAMARICE) at 0.72 and 1.30 kg a.i./ha over the row 21 DAS. However, the use of herbicide was not profitable in upland rice and only slightly profitable in rainfed lowland rice. The complete hand-pulling of in-row weeds in upland rice required 89 d/ha and was not profitable. Selectively removing only the larger weeds reduced hand weeding time to 37 d/ha and increased yields by 11%. The results of this two-year study indicate that effective weed control without external inputs can be attained by row seeding with the donkey-drawn single-row *Super-Eco* seeder, cultivating twice with the *Occidental* hoe and selectively removing in-row weeds by hand-pulling.

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Introduction

Weed control is the major labor activity in direct seeded rice in West Africa. Insufficient labor limits the area that can be successfully cultivated and results in delays in completing hand-weeding, leading to serious yield reductions. The use of animal traction for seeding and weeding upland cereals and peanuts is widespread in Senegal and The Gambia but it is rarely used in rice production. The objectives of the studies described in this article were to: (1) identify a suitable seeder for row seeding rice; (2) evaluate the use of animal traction for the control of inter-row weeds; (3) measure the effect of in-row weed competition on rice yield; and (4) compare hand-pulling and pre- and post-emergence herbicides for the control of in-row weeds. It is anticipated that these technologies can be adopted incrementally by West African rice farmers, including women, in farming systems that have already undergone the transition from a hand hoe to an animal traction-based upland cultivation system.

Literature Review

Direct seeded rice in West Africa is most often broadcast as this requires little time, no equipment, and when correctly done, is an effective way to increase rice competitiveness with weeds (Renaut, 1972). However, broadcast seeded rice must be weeded by hand-pulling which requires an enormous amount of time. Furthermore, weeding must be delayed until the grasses can be differentiated from rice seedlings and the weeds are large enough to be grasped by the hand and pulled. Insufficient time and a desire to avoid a second weeding results in further delays. In their survey of rice farming in the Casamance, Posner et al., (1991) found that rice yield declined 25 kg/ha/day that farmers delayed weed removal beyond 14 DAS.

Row seeding rice can reduce weeding time by allowing interrow cultivation with the hand hoe or animal traction equipment. In Senegal (Posner et al., 1991) and Nigeria (Curfs, 1976), weeding row seeded rice with a combination of hand-hoeing and hand-pulling required only half the time of hand-pulling in broadcast seeded rice. Several authors have shown that row seeded rice can be rapidly weeded with an animal-drawn cultivator (Haddad and Seguy, 1972; Travers, 1975; Patel and Rhodes, 1969). Unfortunately neither the hand hoe nor animal traction equipment control in-row weeds. These weeds can be controlled by hand-pulling or with herbicide. Renaut (1972) reports that in the Ivory Coast hand-pulling in-row weeds once provided adequate control but Curfs (1976) found that in Nigeria in-row weeds had to be removed twice to avoid significant yield reduction. At the International Rice Research Institute (IRRI), Singh et al., (1985) found that pulling in-row weeds resulted in a significant yield increase but was extremely tedious. They suggest that weeding time can be reduced by selectively removing only the larger weeds. This would still reduce weed competition as the effect of weeds on rice yield is influenced by total weed weight rather than by weed density (Noda, 1973). The most widely used rice herbicides in West Africa are oxadiazon (RONSTAR) and the combination of thiobencarb and propanil (TAMARICE). Research in the Ivory Coast (Merlier, 1983), Nigeria (Akobundu, 1981), and Senegal (Diallo, 1984) demonstrated that the preemergence application of oxadiazon at a rate of 1.0 to 1.5 kg a.i./ha suppressed weeds for up to one month. The combination of the preemergence thiobencarb and the postemergence propanil effectively controlled weeds in Ghana (Carson, 1975), Nigeria (Akobundu, 1981), Ivory Coast (Merlier, 1983), and Senegal (Diallo, 1984) when applied at the rate of 0.76 to 2.0 kg a.i. and 1.73 to 2.2 kg a.i./ha at 7 to 21 DAS. A postemergence application enables the farmer to select fields where the herbicide is most needed (Posner and Crawford, 1991). Moody and Mian (1979) suggest that banding over the row can cut herbicide cost in half while still effectively controlling in-row weeds.

Evaluation of an Animal-drawn and a Hand-pulled Seeder for Rice

Two commercially available row seeders for rice were evaluated on-farm in cooperation with women rice farmers. The *SuperEco* is an animal-drawn single row seeder that can be fitted with different plates to seed millet, sorghum, peanut and maize as well as rice (**Fig. 1**). There are an estimated 300 000 *SuperEco* seeders in Senegal (Havard, 1985) and 33 000 in The Gambia (Sumberg and Gilbert, 1988). The *Casamance* is a manual two-row seeder designed to seed in 20 cm rows. Only a few hundred *Casamance* seeders have been introduced in southern Senegal between 1976 and 1980 (Havard, 1985) (**Fig. 2**).

Fig. 1 *SuperEco* seeder (SISMAR, Senegal).

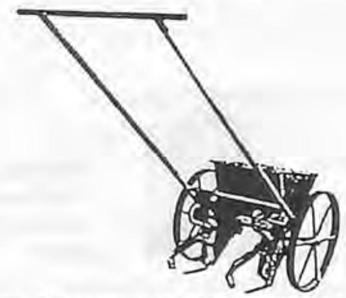

Fig. 2 *Casamance* seeder (SISMAR, Senegal).

Materials and Methods

Prior to field testing, the seeders were calibrated for a seed rate of 80 kg/ha using the short grained upland variety Peking (24.6 g/1 000 seeds). The seeds were collected from the distributors over a 50-m length of concrete drying floor.

The seeders were subsequently tested on six farmers' fields with a range of soil textures from loamy sand to clay and soil moistures from dry to saturated. The *Casamance* seeder was pulled by cooperating women and traction for the *SuperEco* was provided by a donkey in five of the tests and by a horse in the sixth.

Results and Discussion

Seeder calibration — The calibration of *Casamance* seeder was problematic due to the frequent blockage of the seed aper-

Table 1. *SuperEco* Seeder Calibration for Seeding of Upland Rice at 80 kg/ha Seed Rate

Seed Plate[a]	Seed Rate[b] (g/100 m)
30 Tooth peanut	378 +/− 25
24 Hole peanut	331 +/− 23
32 Hole rice	243 +/− 5

[a] At a 30 cm row spacing, 240 g/100 m corresponds to an 80 kg/ha seed rate. At a 40 cm row spacing, 320 g/100 m corresponds to an 80 kg/ha seed rate.
[b] Mean of five 50 m runs.

tures, confirming the observations of Fall (1985) and Havard (1985). This was caused by a breakage of an average of 16% of the seed by the seed distributor when the seeder was calibrated at 160 g/100m of row (80 kg/ha at a 20 cm row spacing). Increasing the aperture opening reduced seed breakage but increased the seed rate to over 150 kg/ha. The *SuperEco* seeder was calibrated with the rice plate and the peanut plates **(Table 1)**. Though the rice plate is a more precise seed plate, the 24-hole peanut plate is widely available and can be used to maintain an 80 kg/ha seed rate when seeding in 40 cm rows.

Field evaluation — The *Casamance* performed satisfactorily only in a well prepared dry seedbed that was free of surface trash. When left on the soil surface following dry tillage, surface trash collected under the opening shoes preventing uniform seed drop. When seeding was delayed, rain compacted the soil, increasing the manual traction effort to a level that was unacceptable to women. The *SuperEco* performed satisfactorily under a wide range of conditions. The problem of surface trash collecting under the seeder was eliminated by removing one of the two covering blades. Under saturated soil conditions both covering tines were removed and the furrow was closed by the weight of the press wheel alone.

Conclusions

The animal-drawn *SuperEco* is a superior seeder to the hand-pulled *Casamance* seeder. The advantages include the following:

Greater versatility — Whereas the *Casamance* is designed to only seed rice, the *SuperEco* is used for the seeding of peanuts and upland cereals as well as rice.

Greater adaptability — Unlike the *Casamance* seeder which functions satisfactorily only under ideal seedbed conditions, the *SuperEco* can be modified to seed under a wide range of conditions.

Greater flexibility — The *Casamance* seeder is designed to seed 20 cm rows. The *SuperEco* can seed either 30 or 40 cm rows, maintaining the recommended seed rate of 80 kg/ha by using either rice or peanut plates.

Greater availability — There are currently 33 000 *SuperEco* seeders in use in The Gambia and over 300 000 in Senegal but no *Casamance* seeders in The Gambia and only a few hundred in Senegal. The majority of women in western Gambia should be able to borrow or rend a *SuperEco* seeder and avoid the expense of purchasing a rice seeder.

Evaluation of Manual, Mechanical and Chemical Methods of Controlling Inter-row and In-row Weeds

The animal-drawn *Occidental* hoe was selected for the study because of its wide availability and light weight **(Fig. 3)**. When equipped with three sweeps it weighs only 18 kg, approximately half what the *Sine* hoe, the other popular animal-drawn cultivator, weighs. The donkey was selected to provide traction because of its greater availability compared to horses and oxen. There were an estimated 26 000 oxen, 16 000 horses and 37 000 donkeys used for draft in The Gambia in 1988 (Sumberg and Gilbert, 1988).

Materials and Methods

In 1987, three farmer-managed tests and one researcher-managed test were carried out. The objective of these exploratory tests was to ascertain the acceptability of the *Occidental* hoe for the control of inter-row weeds. A second objective of the researcher-managed test was to compare alternative methods of in-row weed control. The farmer-managed tests were seeded with the *SuperEco* seeder and cultivated twice with the *Occidental* hoe. Row spacing and in-row weeding were at the discretion of the cooperating farmers. The researcher-managed test was seeded in 30 cm rows (the recommended row spacing for upland rice) and cultivated at 25 and 47

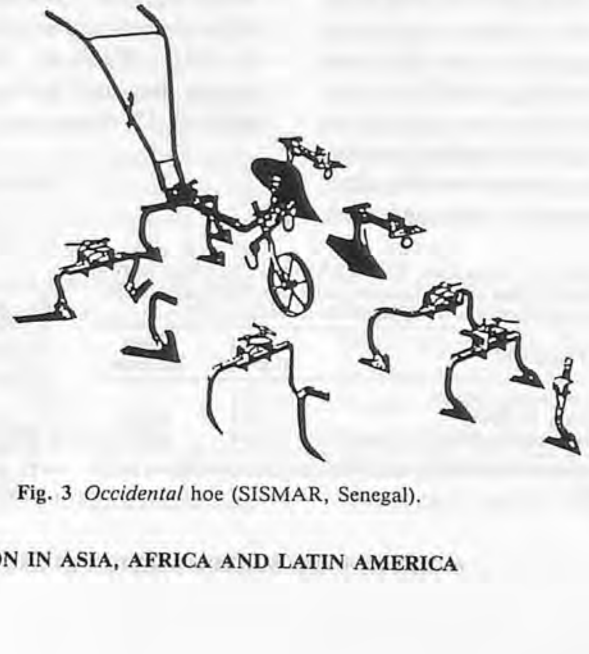

Fig. 3 *Occidental* hoe (SISMAR, Senegal).

DAS with the *Occidental* hoe. In-row weed control treatments included: (1) no in-row weeding; (2) broadcast RONSTAR at 1 DAS; and (3) complete hand-pulling at 52 DAS. Individual plot size was 15 × 43 m (645 m^2) **(Table 2)**.

In 1988 three methods of in-row weed control were compared in researcher-managed trial: (1) no in-row weeding; (2) banded application of TAMARICE at 21 DAS; and (3) selective hand-pulling at 45 DAS. Rice was seeded in 40 cm rows with the *SuperEco* seeder and cultivated at 21 and 42 DAS with the *Occidental* hoe. This was a RCBD with 3 replicates. Individual plot size measured 3 × 35 m (105 m^2) **(Table 2)**.

Table 2. Trial Protocols for the Researcher-managed Evaluation of the Animal-drawn *SuperEco* Seeder and *Occidental* Hoe, Herbicides and Manual Weeding in Direct Seedbed Rice Production

Site	1987 [Upland]	1988 [Rainfed Lowland]
Soil texture	Sandy clay loam	Sandy loam
Plowing	Tractor and Disk harrow	Oxen and Single moldboard plow
Seedbed preparation	—	Oxen and Spike tool harrow
Row spacing	30 cm	40 cm
Seed plate	32 Hole rice plate	24 Hole peanut plate
Variety	Barafita (90 Days)	DJ 12-519 (100 Days)
First cultivation	25 DAS	21 DAS
Second cultivation	47 DAS	42 DAS
Herbicide (T2)	RONSTAR	TAMARICE
Rate (kg a.i./ha)	0.75	0.72/1.30
Application method	Broadcast	Banded
Application time	1 DAS	21 DAS
Hand pulling (T3)	52 DAS Complete	45 DAS Selective
Fertilizer (N-P-K)	48-6.6-12.5	48-6.6-12.5
Harvest	97 DAS	101 DAS

Results and Discussion

Inter-row weed control with the donkey-drawn *Occidental* hoe was highly effective in both the farmer- and researcher-managed tests carried out in 1987. The three participating farmers seeded rice in 40 cm rows rather than the recommended 30 cm and selectively hand-pulled only the larger in-row weeds. In spite of the wider row spacing and the incomplete in-row weeding yields were excellent, ranging from 3.2 to 4.0 t/ha. In Nigeria, Akobundu and Ahissou (1985) found no significant yield difference when rice was seeded in 15, 30, or 45 cm rows when weeds were adequately controlled and Haddad and Seguy (1972) recommend the wider row spacing in order to facilitate animal traction weeding and reduce weeding time. In the researcher-managed tests, weeding time was 12.2 h/ha at a 30 cm row spacing. Increasing the row width to 40 cm, the spacing preferred by the farmers, would theoretically have reduced weeding time by 25%. In the researcher-managed test, RONSTAR (T2) increased yields by 28% and complete removal of in-row weeds (T3) by 41% compared to no in-row weed control (T1) **(Table 3)**. The complete hand-pulling of weeds required 89 d/ha. In contrast, the selective hand-pulling of in-row weeds by the participating farmers required substantially less labor.

In the 1988 trial, banded TAMARICE (T2) increased yields by 16% and selective hand-pulling of in-row weeds (T3) by 11% compared to inter-row cultivation alone (T1) **(Table 4)**. When banded over the row, TAMARICE significantly reduced weed weight at 45 DAS **(Table 4)**. Selectively hand-pulling only the larger weeds required 52 fewer days than in 1987 but resulted in only a 11% yield increase compared to no in-row control (T1).

When calculating the benefit of herbicide or followup hand-weeding in mechanically weeded rice, the increased yields are offset by the following costs: (1) herbicide; (2) sprayer; (3) labor for spraying; (4) labor for hand-weeding; and (5) labor for harvesting the additional yield. In the 1987 researcher-managed test, the costs associated with using RONSTAR exceeded the value of the additional yield and there was a net loss of $3.95/ha. However in the 1988 trial, banded TAMARICE was slightly profitable with a net gain of $11.39/ha. The complete hand-pulling of weeds in 1987 resulted in a net loss of $10.89/ha. This was due to the excessive number of days needed to complete the weeding. Selectively removing only the larger weeds, as done by

Table 3. Effect of Broadcast RONSTAR or Complete In-row Hand-pulling in Combination with Two Mechanical Inter-row Cultivations on Upland Rice Yield, 1987

Treatment*	Yield (kg/ha)	Yield Increase
T1 No in-row weed control	1 291	—
T2 RONSTAR (1 DAS)	1 655	28%
T3 Complete hand-pulling (52 DAS)	1 814	41%

*All three treatments were cultivated with the *Occidental* hoe at 25 and 47 DAS.

Table 4. Effect of Banded TAMARICE or Selective In-row Hand-pulling on Rice Yield and on Weed Weights in Rainfed Lowland Rice, 1988

Treatment*	Yield (kg/ha)	Yield Increase	Weed Wt.** (kg dm/ha)
T1 No in-row weed control	3 235	—	475
T2 Banded Tamarice (21 DAS)	3 759	16%	130
T3 Selective hand-pulling (45 DAS)	3 597	11%	625
$LSD_{.05}$	ns		265 kg/ha
CV	8.2%		28.6%

* All three treatments were cultivated with the *Occidental* hoe at 21 and 42 DAS.

**T1 (no in-row weed control) and T3 (selective hand pulling) had received identical treatment at the time of weed sampling.

the participating farmers the previous year, was profitable in the 1988 trial with a net gain of $8.95.

Conclusion

Inter-row cultivation with the donkey-drawn occidental hoe — Inter-row cultivation with the animal-drawn Occidental effectively controlled inter-row weeds, resulting in a yield of 1.3 t/ha in upland rice in 1987 and 3.2 t/ha in rainfed lowland rice in 1988 with no control of in-row weeds. Participating farmers demonstrated that increasing the row width to 40 cm can reduce the time needed for seeding and inter-row weeding without depressing yields.

In-row weed control with pre- and post-emergence herbicides — Both RONSTAR in 1987 and TAMARICE in 1988 effectively controlled weeds and increased yields over no in-row weed control. However, when inter-row weeds were mechanically controlled, a broadcast application of RONSTAR at 3 ℓ/ha was not profitable on low yielding upland rice and a post-emergence banded application of TAMARICE at the rate of 3 ℓ/ha was only slightly profitable on high yielding rainfed lowland rice. Herbicide profitability can be increased by directing its use to high yield potential situations and by reducing herbicide quantity by banding.

Control of in-row weeds by hand-pulling — The hand-pulling of inter-row weeds is an effective but time consuming method of weed control. As demonstrated by participating farmers in 1987 and confirmed in the researcher-managed trial in 1988, the time required for in-row hand-weeding is less when only the larger weeds are selectively removed.

Recommendations

A technical package for improved weed control in direct seeded rice has been identified that does not require the purchase of external inputs. Components of this package include:

(1) Row seeding with the animal-drawn *SuperEco* seeder in 40 cm rows using the 24-hole peanut plate for a seed rate of 80 kg/ha;
(2) Controlling inter-row weeds at 21 and 42 DAS with the animal-drawn *Occidental* hoe; and
(3) Controlling in-row weeds by selectively hand-pulling only the larger weeds.

Farmer Adoption of Mechanized Row Seeding (1988-1992)

A survey was conducted in three villages in 1989 to ascertain the rate of adoption of the SuperEco seeder for row seeding rice fields that are normally broadcast seeded. Adoption rates of 25%, 44% and 63% were extremely encouraging (Jones, 1989). Factors that encouraged adoption included animal ownership and participation in training programs. In 1989 the Department of Agricultural Research organized a workshop on low external input rice production technologies, including mechanized row seeding (DAR, 1989). Workshop participants included field staff of five non-governmental organizations who work directly with subsistence rice farmers as well as government extension personnel. Since 1989 the adoption of mechanized seeding has continued to increase. In several villages it has become commonplace to observe men assisting women in rice seeding with donkeys and SuperEco seeders (Leisz, 1992).

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ABSTRACTS

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

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Status of Water Pumping Wind Mills in Orissa, India: Dash, S.K., Asst. Director, Regional Extension Service Centre; Sahoo, P.K., Res. Associate, Dept. of F.M.P; Khan, Md. K., Lect. Gr. I, Dept. of A.P. and F.E.; Mohanty, S.N., Head, Dept. of A.P. and F.E., respectively, College of Agril. Engg. and Tech., O.U.A.T., Bhubaneswar, India.

Water pumping wind mills located at different parts of Orissa, India were surveyed in order understand their performance, technical back up, maintenance and different post-installation problems faced by the wind mill owners. It was observed that almost 66% out of the total 307 wind mills installed in Orissa were completely out of order due to various problems such as poor quality standard of materials and fabrication defects (1%), site and installation problems (8.5%) and poor maintenance (43.6%). The natural calamities and other personal factors were also responsible in 9.8% and 2.9% of the cases, respectively, for the non-functioning of the wind mills. About 90% of the wind mill owners did not give proper attention to the post-installation measures of their wind mills.

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Some Investigation of the Design Parameters of Sorghum and Pearl Millet Harvester: Yadava, G.C., Scientist, Central Institute of Agric. Eng. (I.C.A.R.), Nabibagh, Berasia Road, Bhopal 462018, M.P., India.

Sorghum (*Biocolor K. Moenech*) and pearl millet (*Pennisetum typholies L.*) are the main cereal crops grown in India under drylalnd conditions. These crops have thick stems and cobs are stripped manually. The existing harvesters with reciprocating cutter bars are not suitable for cob cutting of these crops. Knife and system parameters were determined for cutting the sorghum and pearl millet crops under quasi-static conditions.

Five geometries of rotary cutting elements namely; logarithmic spiral, logarithmic wedge, flat, spike stright and spike curved were designed and developed with a constant diameter of 200 mm. They were fabricated from 3 mm thich high speed steel. Each geometry was tried with two knives and four knives. These cutting elements were evaluated with a set of counter cutting edges with fixed opening of 30 degrees. For the evaluation of the rotary cutting elements, a test rig was developed. The cutting elements were mounted on the test rig and they were evaluated under simulated laboratory conditions for nipping cobs from sorghum and pearl millet plant specimen on a modified soil bin. Each cutting elements were tested at 5 different cutting speeds ranging from 100-500 revolution/min in steps of 100 revolution/min and machine forward speed of 1.5 km/h.

A prediction equation was developed to determine the cutting energy. The predicted values were inclose agreement with the experimental values.

The findings of the research work were applied in the development of a two-row sorghum cob harvester. The prototypes were field tested. The hand push unit gave an output of 0.04-0.1 ha/h. The bullock drawn unit gave an out-put of 0.18-0.27 ha/h.

It is expected that the findings will not only help in the mechanization of sorghum and pearl millet harvesting but would have an application for development of stripper/harvester for other thick stemed and wide spaced crops.

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Mechanization of Agriculture — A Microanalysis in Tamil Nadu: Punitha, N., Assit. Professor; Srinivasan, R., Professor, respectively, Dept. of Agric. Econ., Tamil Nadu Agrl. Univ., Coimbatore-641003, India.

A study on farm mechanization was conducted in Periyar District of Tamil Nadu. It included a farm survey of 110 farm households which were grouped into tractor, power tiller and bullock farms. The study emphasized an estimation of optimum size of the farm and operation of machinery and selection of appropriate machinery for the farm holdings. The optimum size of the tractor and power tiller farms were 40.46 ha and 21.95 ha, respectively. The breakeven points for tractor and power tiller usage were 1 658.86 h and 1 248.52 h, respectively. A comparative analysis of tractor and power tiller farms suggested a better suitability power tillers to farm holdings of Tamil Nadu compared to tractor.

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Effect of Sowing Techniques in Wheat Production: Razzaq, Abdul, Senior Subject Matter Specialist, (Engg.); Karim, Abdul, Assit. Research Officer, Adaptive Research Farm, Sheikhupura, Pakistan.

In this study, the effect of three sowing techniques viz. broadcasting and straight and cross drilling in wheat production was investigated. The influence of seed rate by varying it as 100, 125 and 150 kg/ha under drilling method was also studied. Cross drilling in combination with 125 kg/ha seed proved to be the superior technique as it significantly enhanced germination, tillering and yield of wheat crop and also contributed the highest return of Rs. 5.39 per unit expenditure additional to broadcasting.

241

Field Tractive Performance Comparison Between 2WD and 4WD Modes in Tractor Operation: Jenane, Chakib, Assit. Professor, Institut Agronomique et Veterinaire Hassan II, Dept. de machinisme Agricole Rabat, Morocco; Bashford, Leonard L., Professor, University of Nebraska-Lincoln, Biological Systems Eng. Dept. Lincoln, NE 68583-0726, USA.

Field tests were conducted in order to evaluate and compare the tractive performance of a tractor when operated in the two- and four-wheel drive mode. Traction data were obtained from drawbar tests on five different soil surfaces, including stubble, moldboard plowed, disk plowed, chisel plowed and offset disked fields. Tractive performance was evaluated by comparing the relationships of slip, dynamic traction ratio and tractive efficiency. Results show that the more the soil is disturbed, the lower the tractive performance. Also, the highest performance was obtained when the tractor was operated in the four-wheel drive mode.

242

An Analysis of Maintenance of Tractors Based on CPM and Pert Techniques: Rangasamy, K.; Ranganathan, C.R.; Balasubramanian, M., Prof. and Head, Dept. of Farm Machinery, respectively, College of Agric. Eng., Tamil Nadu Agricultural University, Coimbatore - 641 003, India.

CPM and PERT techniques were applied in analyzing the major overhauling of tractors. These techniques identified 47 subsystems or activities. The expected completion of all events required 105 h with a variance of 24 h. Total labour cost for the entire overhauling was Rs. 4 294 (about US$165). The analysis shows that the probability of completing the overhauling job ranged from 0.159 to 0.846 for completion durations of 100 to 110 h.

245

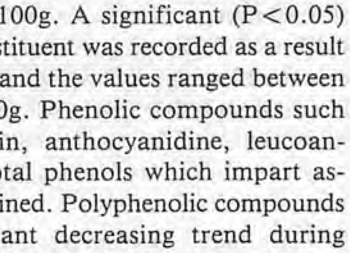
Biochemical Quality and Storage Stability of Solar Dried Persimmons: Chaudry, M. Ashraf, Scientific Officer; Bibi, N.; Sattar, A., respectively; Nuclear Institute for Food and Agriculture (NIFA), Tarnab, Peshawar, Pakistan.

Persimmon fruit is a recent introduction in the North-West Frontier Province of Pakistan and its cultivation is fast increasing. The paper reports the development of a solar drying process for this nutritious fruit. The ripened but hard fruit was sliced (2.5-3.0 mm) and sulphited (0.2% SO_2, 3 min.) before drying in a solar cabinet dryer developed at the Institute. The drying process took about 10 h for the samples to reach a moisture content of 15-16%. Storage studies indicated that the moisture content of dried fruit ranged between 15.3 to 15.4% after 6 months at ambient temperature. The ascorbic acid content of the dried fruit ranged between 116.0 to 126.0 mg/100g. A significant ($P<0.05$) reduction in this constituent was recorded as a result of 6 months storage and the values ranged between 102 and 109 mg/100g. Phenolic compounds such as sinapine, catechin, anthocyanidine, leucoanthocyanidine and total phenols which impart astrigency were determined. Polyphenolic compounds indicated a significant decreasing trend during storage after solar drying. Sensoric evaluations revealed that sulphited samples were rated higher (7.8) than control samples (6.1) for their overall acceptability during 6 months storage.

247

Development of a Horizontal Palm Fruit Digester (Futo-Digester): Asoegwu, S.N.; Ekpe, C.; Adebayo, K., Dept. of Agric. Eng., Federal University of technology, P.M.B. 1526, Owerri, Imo State, Nigeria.

A motorized horizontal palm fruit digester **(Figure)** was designed and developed at the Federal University of Technology, Owerri (FUTO). The performance of



the digester was evaluated using cylinder speed, feed rate, and time to macerate, to monitor such variables as maceration efficiency, throughput capacity, material loss, torque, power efficiency and performance index.

The maceration work done by the machine was thorough and the discharge smooth and continuous provided that the machine was fed continuously through the top-feed hopper. The digester performed best at cylinder speeds between 350 and 450 rpm and at feed rates of 8.5 to 10.5 kg/min, giving maceration efficiency of over 94%, material loss of less than 2.8%, throughput capacity of over 480 kg/h., power efficiency of over 75% and performance index of over 19.2 t/kWh.

249

Effect of Rotary Tillage on Bengal Gram after Paddy Harvesting in Heavy Black Soil Condition: Prasad J., Scientist, Selection Grade (Farm Machinery and Power); Devnani, R.S., Principal Scientist & Project Coordinator, AICRP on Farm Implements and Machinery, Central Institute of Agric. Eng., Nabi Bagh, Berasia Road, Bhopal, Madhya Pradesh - 462 018, India.

The study was conducted with four tillage treatments consisting of rotavator and conventional tillage equipments. The total operational time and fuel consumption per unit area basis was minimum in the case of single rotavation as compared to other tillage treatments. The quality of seedbed preparation in terms of bulk density index and mean mass diameter of soil aggregates was better even by single rotavation as compared to conventional tillage equipments. The difference in grain yield of Bengal gram crop due to treatments was not significant. The specific energy consumption in seedbed preparation was the lowest in the case of single rotavation. Although hourly cost of operation of tractor with rotavator was high the cost of operation on area basis was minimum for the single operation with rotavator as compared to other tillage treatments involving nmulti passes over the field.

250

Status of Oilseed and Animal Feed Processing Plants in China: Kachru, R.P., Head; Shukla, B.D., Senior Scientist, Post Harvest Eng. Div., Central Institute of Agric. Engineering, Nabi Bagh, Berasia Road, Bhopal-462 018, India.

The authors, were members of an Indian delegation deputed by the Government of India (GOI) to China during June 12-26, 1990, to study oil expelling technology. The paper describes the status of oil seed and animal feed processing plants existing in China.

The major oilseeds in China are peanut, rape seed and soybean amounting to an annual production of 18 million t and are being processed by screw expellers/hydraulic presses. Various models of screw oil expellers costing between Rs. 13 000/- (domestic level) to Rs. 4 lakh (complete plant) with varying handling capacities of 125-210 kg/h giving an oil recovery as high as 92% in single pass are in use in China. Manual/power hydraulic presses with capacities of 800-1 200 kg/24 h and costing about Rs. 12 000/- are also in use with an oil recovery as high as 90-91%.

Various types of animal feed processing plants with handling capacities ranging from 500 to 1 000 kg/h and costing between Rs. 85 000 to Rs. 3.5 lakh are available in China.

The authors are of the view that oil expelling technology available in China is most suitable for Indian conditions. Thus, it is recommended that few units of each model of screw and hydraulic press could be imported for evaluating their performance at few selected locations in India. Thereafter, negotiations could be made with the Chinese authorities to either directly import a few hundred units of the expellers and/or manufacture them in India for their wider use in the country.

251

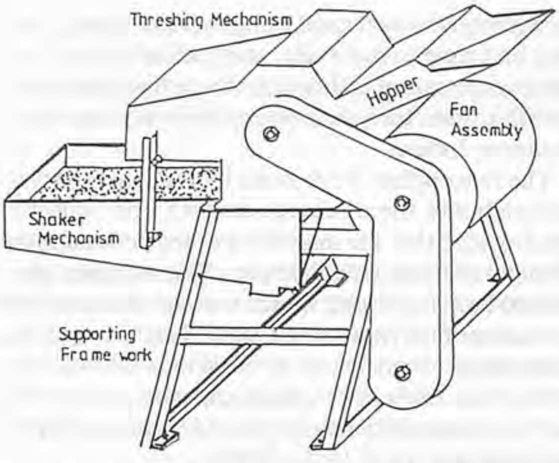
A Study of the Design of a Wind Powered Water Pumping Set Suitable for Bangladesh: Islam, Md. Quamrul, Professor; Islam, A.K.M. Sadrul, Assoc. Professor; Al Nur, Maglub, Assist. Professor, Dept. of Mech. Engg., Bangladesh Univ. of Engg. & Tech., Dhaka 1000, Bangladesh; Kamal, Imtiaz, Asst. Engineer, Institute of Nuclear Science & Tech., Bangladesh Atomic Energy Commission, Dhaka, Bangladesh.

This paper describes a theoretical investigation of the design of a wind powered water pumping set suitable for irrigation in Bangladesh. The optimum rotor configuration for twist and chord is determined using the momentum theory and blade element theory assuming zero drag and average wind velocity at Chittagong for a rotor without coning or tilting. The coning angle and mass distribution are determined from an iterative procedure considering the effect of drag. Then considering the designed power of the wind turbine, a suitable piston pump has been designed. The performance of the rotor with and without the pump is studied. The numerical results obtained with the present method for the wind turbine agree well with experimental and other numerical data.

252

Performance of Sorghum Thresher in Threshing Cowpea on the Stalk: Asota, C.N., Lecturer, Agric. Eng. Dept., Ahmadu Bello University, Zaria, Nigeria.

The effects of some factors (pod/stalk ratio, drum speed and fan speed) upon the performance of a sorghum thresher **(Figure)** on threshing cowpea pods on the stalk were studied. Analysis of the data for a given concave/cylinder clearance suggests that the quality of the threshed material with respect to seed breakage depends to some extent on the pod/stalk ratio but the speed of the threshing drum was the most significant factor. Increase in the speed increased the threshing effectiveness while substantially increasing seed breakage. The relations governing the quality of threshed cowpea material were also identified from the data. Mechanical damage to threshed material and the effectiveness of the thresher were simple quadratic functions of



the cylinder speed and pod/stalk ratio. Examination of the experimental factor space showed that the optimum conditions necessary for effective threshing and cleaning do not coincide with that necessary to minimize breakage. On the basis of this analysis, it was possible to seek a compromise between these factors in specifying the parameters for an optimum design of a cowpea-on-the-shoot thresher. ■■

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12th CIGR Conference

The 12th International Commission of Agricultural Engineering (CIGR) congress was held at the University of Milan. The event was attended by 700 experts from 54 countries.

A report of 3 000 pages already available, covering all aspects of agricultural engineering, from land, water, and environmental resources to farm buildings, mechanization, energy saving, and farm management.

Club Bologna, 5th Members Meeting

Club Bologna is a group of experts for making strategies for the development of agricultural mechanization. The club 5th members meeting was held at University of Milan on 2nd September, 1994.

There were more than fifty participant, including members and guest speakers from all over the world.

Rice and Art Combined in Sculpture

A prominent artist Mr. Mitsuaki Tanabe donated a valuable stainless steel sculpture of a greatly enlarged grain of wild rice to IRRI. The sculpture was presented to IRRI director General in a special ceremony, saying it symbolizes his appeal to improve understanding of the importance of wild rice in nature and to people.

According to his views International Rice research Institute (IRRI) is an ideal place to have his work on permanent display.

44th Annual Fall Convention of Farm Equipment Manufacturers Association

Nov. 5-9, 1994
St. Louis, MO, USA.

This convention has its objective for making strategies for tomorrow. Tomorrow agribusiness market will require strategies for change and innovation.

Asian Farming Symposium 1994

Nov. 7-11, 1994
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Contact:
Asian Farming System Symposium Secretariat, P.O. Box 70, Peradeniya, Sri Lanka. Tel: 94-8-88081/88206, Fax: 94-8-32817/88206/32517, Telex: 22959 PRAGEM CE.

4th SEAES '94 - An International Conference

Nov. 21-23, 1994
Rayong, Thailand

Contact:
Dr. Kitti Intaranont, Dept. of Industrial Engineering, Faculty of Engineering, Chulalongkorn University, Bangkok 10300, Thailand. Tel: (66-2) 218 6410, Fax: (66-2) 253 6161 or 218 6411.

The Royal Smithfield Show

Nov. 27-30, 1994
London, UK.

The Royal Smithfield Show will be held at Earls Court Exhibition Centre, London, for the development of farmers knowledge.

There are already more than 306 exhibitors committed to the show. These include companies from France, Holland, Italy, Germany and Scandinavia.

For further information contact: Robin Hicks, Show Director, Royal Smithfield Show, P & O Events Ltd., Earls Court Exhibition Centre, Warwick Road, London SW5 9TA. Tel: 071 370 8224, Fax: 071 370 8142.

International Agricultural Engineering Conference 1994

Dec. 6-9, 1994
Bangkok, Thailand

Contact:
Dr. V.M. Salokhe, Associate Professor, AFE Program, SERD, Asian Institute of Technology, G.P.O. Box 2754, Bangkok, Thailand - 10501. Tel: (66-2) 524 5479 / 524 5489, Fax: (66-2) 524 6200.

International Symposium on Harvest and Postharvest Technologies for Fresh Fruits and Vegetables

Feb. 20-23, 1995
Guanajunato, Mexico

Contact:
Mr. Kyung H. Yoo, Chairman of Publicity Committee, Dept. of Agricultural Engineering, Auburn University, Albama - 34689-5417, USA.

☆ ☆ ☆

Micro-irrigation for a Changing World: Conserving Resources / Preserving the Environment

April 2-6, 1995
Orlando, Florida, USA.

Contact:
Allen Smajstrla, University of Florida, Ag. Eng. Department, Gainsesville, Florida - 32611, USA. Tel: (904) 392 9295, Fax: (904) 392 4092.

The International Symposium on Water Quality Modelling

April 2-5, 1995
Kissimmee, Florida, USA

Contact:
James Backer, Dept. of Ag. & Biosystem Engg., Davidsen Hall, Iowa State University, Ames, IA 50011-3080, USA.

5th North American Regional Meeting/Workshop - Advanced Technology in Vehicle-Terrain Interaction

May 10-12, 1995
Saskatoon, Canada

Contact:
Dr. R. Lal Kushwaha, Ag. & Bio-resources Eng. Dept., University of Saskatchewan, Saskatoon, SK, S7N 0W0, Canada. Tel: 306-966 5313, Fax: 306-966 5334.

XVIIIth International Society for Photometry and Remote Sensing (ISPRS) Congress

July 9-19, 1996
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Contact:
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New Contour Probe from "Agritech doppler"

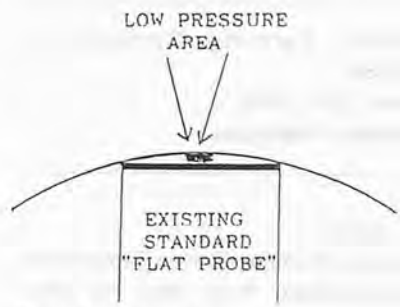

Fig. 1 Poor contact.

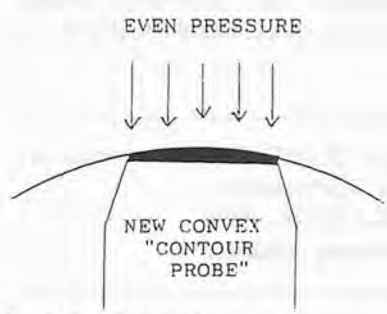

Fig. 2 Excellent contact.

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Fig. Safety and quickly Swissmex-152 granule applicator places precise dosage of fungicide or nematicide at base of tree.

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Salinisation of Land and Water Resources

(Australia)

by F. Ghassemi, A.j. Jakeman and H.A. Nix, Centre for Resource and Environmental Studies, Australian National University

Salinisation of land and water is an increasing problem in many areas of the world, particularly in arid and semi-arid regions where irrigation is a contributory factor.

This book assesses the extent, human causes and management of salinisation. The first part of the book provides an extended review of general issues, including a history of secondary salinisation, followed by a discussion of the trends in area irrigated, the process of salinisation, extent of land and water salinisation and their associated.

Jahrbuch Agrartechnik - Yearbook Agricultural Engineering

(Germany)

edited by Dr. Ing. E.h.H.J. Matthies and Dr. agr. F. Meier.

The sixth edition of the Yearbook Agricultural Engineering has just been published. As in 1991 and 1992, this edition is bilingual (German and English).

The lively approval from Germany and from abroad shows that this yearbook - in the market since 1988 - has won recognition everywhere and gives the experts in Europe and in other countries of the world a summarized survey of research work and the evolution of the agricultural engineering industry.

The previous structure has been maintained for the sixth edition, too: Besides the presentation of the economic development of the German agricultural engineering industry and of standards for the application of electronics in mobile agricultural engineering, the yearbook reports on the classical domain of agricultural engineering, i.e. from the tractor via the technology in field operations to the yard and barn technology. This is rounded off by reports relating to environmental engineering, power engineering, tropical and subtropical agricultural engineering, municipal services engineering and agricultural machinery testing as well as to the results of farm work science. New subjects are bio engineering and testing and working of plant protection equipment in the former GDR.

This time again the yearbook contains a voluminous bibliography which considers not only the national publications but also the international documentations in the individual sectors.

The book offers many details to the expert, but the quick reader, too, gets a good and informative survey of the sector of agricutural engineering.

1993. 253 pages, Booklet DM65, ISBN 3-8163-0293-9.

Published by VDI-Gesellschaft Agrartechnik, Kuratorium für Technik und Bauwesen in der Landwirtschaft (KTBL), Max-Eyth-Gesellschaft für Agrartechnik (MEG), Landmaschinen- und Ackerschlepper-Vereiningung (LAV) im VDMA.

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A Manual of Rice Seed Health Testing

(Philippines)

The manual compiles important information about common seedborne rice diseases and rice seed contaminants, details about disease-causing organisms, and methods of detecting their presence.

Seed health refers primarily to the presence or absence of disease-causing organisms such as fungi, nematodes, bacteria, viruses, and insects, Seed health is crucial for good crop production.

Rice seed is exchanged widely for both scientific and commercial purposes. Shortly after its founding in 1960, IRRI started exchanging seed for scientific use. In recent years, these exchanges have occurred with increasing frequency. Between 1985 and 1990, IRRI handled 936 547 seed packets, each weighing from a few grams to a few kilos. In 1992, IRRI dispatched 94 836 packets to rice scientists worldwide and received 6 270 packets from outside of the Philippines.

"This exchange of rice germplasm can be expected to increase as scientists in national breeding programs intensify their work and strive to increase rice yields by breeding resistance to pests and tolerance for stresses, such as drought and adverse soils, into new varieties," says Dr. Klaus Lampe, IRRI director general.

With the exchange of seeds, however, comes the danger of introducing pests and microorganisms. IRRI established its Seed Health Unit in 1983 in cooperation with the Plant Quarantine Service of the Bureau of Plant Industry of the Philippines. The unit works to ensure that incoming rice seed consigned to IRRI meets or exceeds Philippine quarantine requirements and that the seed IRRI sends out meets the requirements of other countries.

A Manual of Rice Seed Health Testing is available from Communication and Publications Services, IRRI, P.O. Box 933, Manila 1099, Philippines.

For additional information about this article, contact Paul M. Icamina, IRRI Information Center, P.O. Box 933, Manila 1099, Philippines; Tel: (63-2) 818-1926 or (63-2) 88-83-51; Fax: (63-2) 818-2087.

The Proceeding of Microenterprise development June 1-3, 1994, IRRI

(Philippines)

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Application of Advanced Information Technologies: Effective Management of Natural Resources

Proceedings of 1993 Conference

(U.S.A.)

edited by Conrad D. Heatwole

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Computers in Agriculture 1994

Proceedings of the 5th International Conference

(U.S.A.)

edited by Dennis G. Walson, Fedro S. Zazueta and Tony V. Harrison

Sponsored by The University of Florida Institute of Food and Agricultural Sciences and co-sponsored by the Information and Electrical technologies Division of ASAE, this proceedings provides insight into the use of computers in agriculture.

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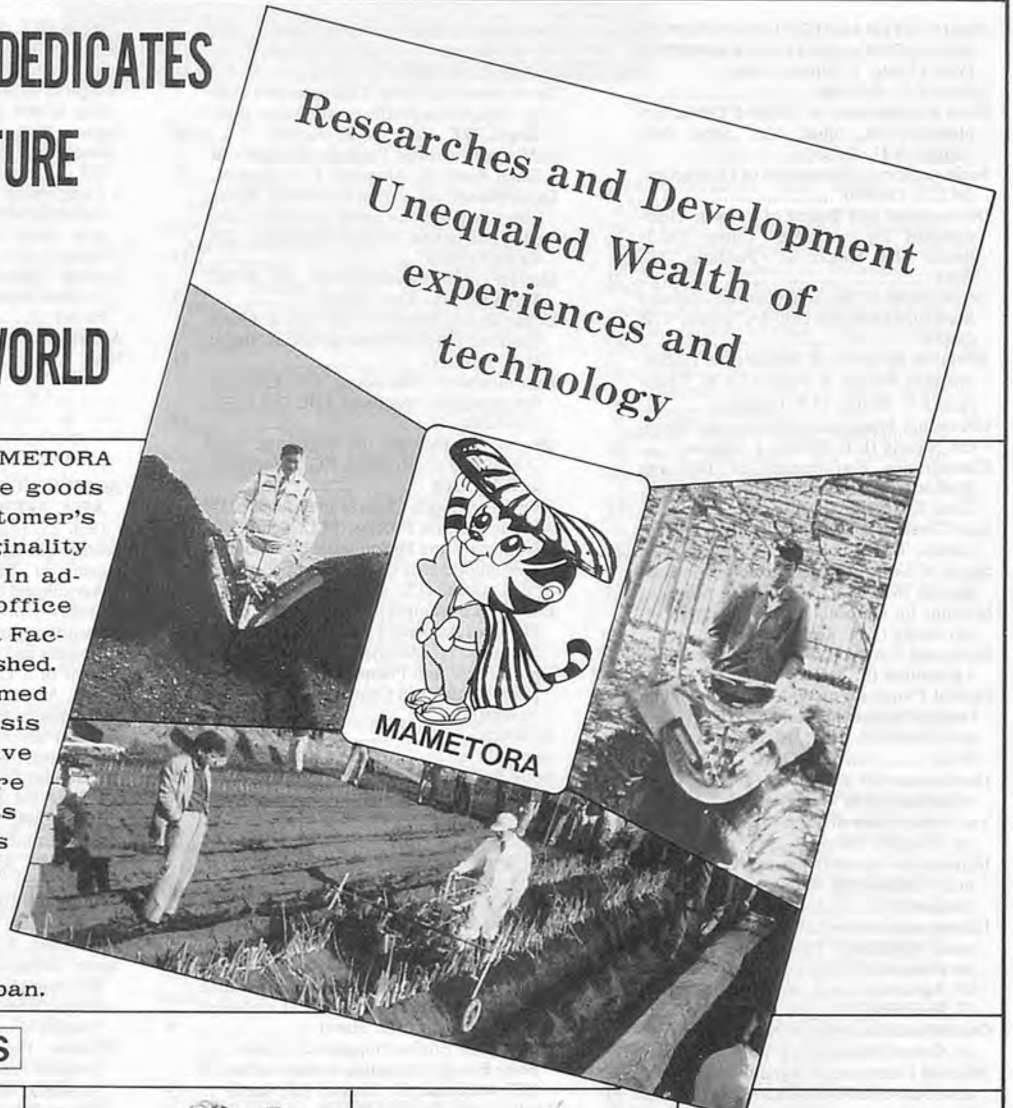

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