International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.29, NO.2, SPRING 1998

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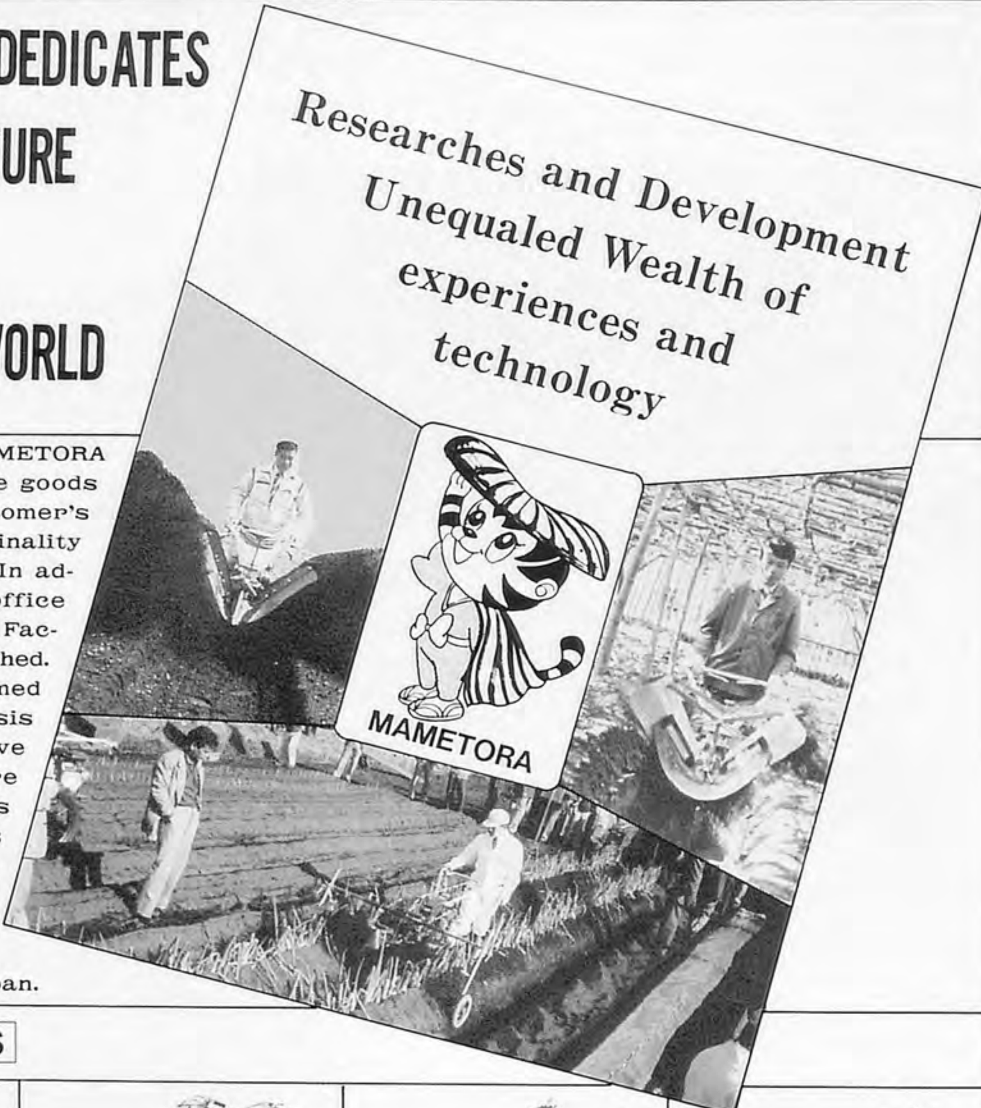

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Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101, Japan

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
SHIN-NORIN Building
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101 Japan
Printed in Japan

This is the 99th issue since its maiden issue in the Spring of 1971

EDITORIAL

The Need to Raise Land Productivity

As the 21st Century will be upon us in just about 30 more months from now, one wonders if the available food supply will be adequate to feed the world's population which is currently increasing by nearly 100 million a year. The race between population growth and food availability has never been more critical with the latter lagging dangerously behind. This race leaves policy makers only a little hope to expand cultivable land areas from the earth's limited supply. That being the case, the remaining option is for us to raise land productivity in order to increase food availability.

The recently concluded International Commission of Agricultural Engineering (CIGR) World Congress in Rabat, Morocco last February addressed the issue of raising land productivity in more ways than one. The Congress was a meeting of the minds of a large number of agricultural engineers from around the world who exchanged experiences among themselves and discussed emerging useful research results. For example, the Congress examined the feasibility of a notable and novel idea of expediting the spread of important research results via the Internet through an ''electronic journal''. When operational, the journal should deliver, free of charge, instant news for use by recipients all over the world. This novel innovation on communication technology is bound to revolutionize the agriculture profession, particularly the promotion of agricultural mechanization world-wide as the 21st Century is ushered in.

Additionally, the Morocco successful experience in agriculture is an eye opener for many regions of the world where rainfall is scanty and evaporation is fast like that which is the case in that country. The secret is nothing new as it only involves the widespread operation of a wellequipped, efficient irrigation system that keeps land productivity at high level.

More and more, agricultural engineers are being called to lead the effort at solving the food problem through a more effective use of limited resources such as land, irrigation water and farm energy. Inevitably, agricultural machineries are being seen to be playing a stellar role in that effort. For example, farm machineries will be a requisite during the busiest seasons in the farm considering the shortage of labor even in developing countries. In this regard, it is notable that India, for instance, is already expanding its manufacture and sales of tractors — a clear indication indeed that farm machineries is an idea whose time has come. It better be so that land productivity can be raised, hence help solve the world's food problem.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April, 1998

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Development of Instrumented Tillage Meter

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Abstract

A simple and reliable instrumentation system capable of measuring the forces acting on a tillage tool was developed. It measures the forces through strain gauged transducers and includes an instrumentation system for signal conditioning, calibration, data logging and retrieval to a computer. The system was evaluated in an experiment comparing the measurement of forces on a tillage tool at two operating speeds. The data proves the efficacy of the system for tillage studies. The system is simple and easy to build in an Asian research environment.

Introduction

An instrumented soil bin has become the standard prerequisite for tillage research in the laboratory. Likewise, the tillage meter is a must for the conduct of field studies on tillage tools. The assessment of forces and moments acting on a tillage tool is a prerequisite for its design. Sophisticated instrumentation systems were developed and used for this purpose (Owen et al., 1985; O'Dogherty, 1986; Thomson and Shinners, 1989; Graham et al., 1990). But an indigenous, simple, easy to build tillage meter is a long felt need of the Asian researchers. This study contemplated the development of one such system.

Materials and Methods

The Construction of Dynamometer

The developed dynamometer includes six force transducers and an 'L' shaped tool bar with a cross beam on it **(Fig. 1)**. Of these six sensors, L_3 measuring a horizontal force, V_1 and V_2 measuring the vertical forces and S_1 the lateral force, acting on the tool, were strain gauged load cells. L_1 and L_2 measuring the other two horizontal forces were sensors by virtue of strain gauging the cross beam itself as a beam transducer. By knowing the forces sensed by each transducer in response to an applied load on the tillage tool and the appropriate moment arms with reference to a coordinate system, computation of forces and moments is possible. The draft, vertical and lateral forces acting on the tool along with the locations through which they pass can be computed.

The system of forces could be represented by:

i. a single resultant

$$R = \sqrt{L^2 + S^2 + V^2}$$

passing through the point (x_1, 0, z_1) at an angle $\alpha = \tan^{-1}$ (S/L) in the horizontal plane and $\beta = \tan^{-1}$ (V/L) in the vertical plane.

ii. a couple of magnitude

$$C = \{x_1 - (x_2 + (b - d)/2\}V - (z_1 + a)S$$

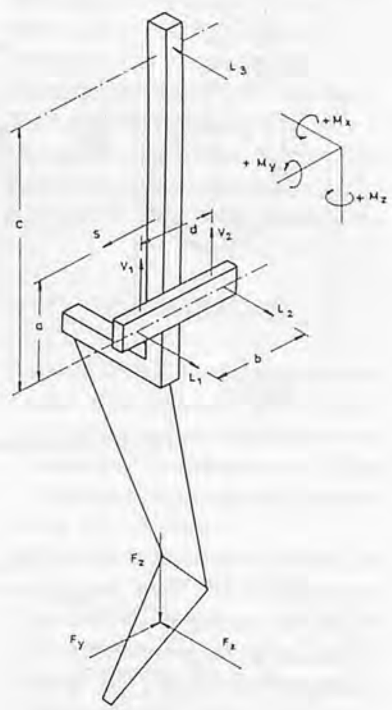

Fig. 1 Arrangement of transducers on the dynamometer.

in the vertical plane to the soil surface.

The construction of the dynamometer frame with transducers and the tool bar is shown in **Fig. 2**. All the load cells are of 1 000 N capacity, universal type, working at 5V excitation and 2.0 gage factor. The loads L_1 and L_2 are sensed by strain gauges cemented on the cross bar of the dynamometer. The bar is of aluminium alloy of 50 × 20 mm^2 section and of 280 mm long designed to transduce 3 000 N. Four strain gauges are used on either trans-

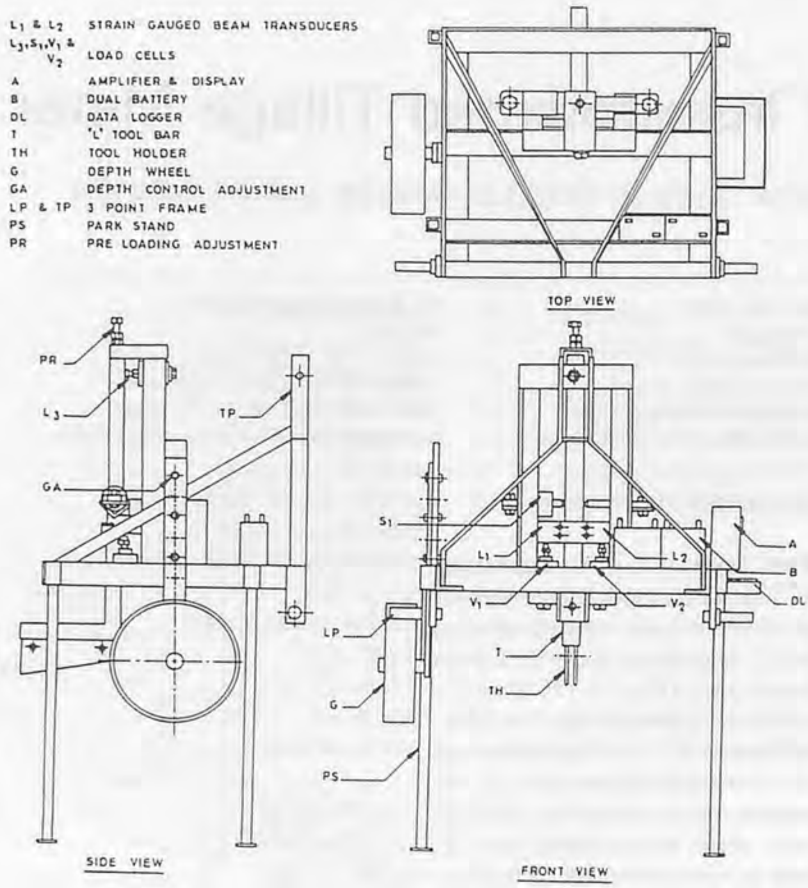

Fig. 2 Construction of the dynamometer.

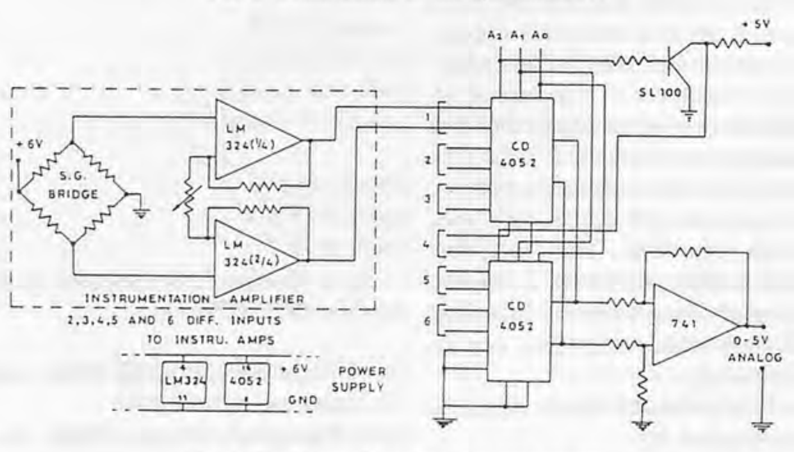

Fig. 3 Signal amplifiers and the multiplexer.

ducer in full bridge configuration. Since it is basically a beam transducer, linear response is conveniently obtained. Excitation used is 5V DC.

The Instrumentation

Since the system has six transducers, instrumenting and recording all the six readings simultaneously would make the system bulky and costly. Hence the six signals are multi-plexed and any one force recorded at any instant **(Fig. 3)**. Each of the six transducers has a separate instrumentation amplifier with necessary balancing circuits, the outputs of which are multiplexed and led to a digital datalogger for storing the information. The first stage amplifier is designed in a differential output mode with two NE 324 operational amplifier integrated circuit (IC) chips. This amplifier constituted the first half of the standard 3 operational amplifier instrumentation amplifier configuration. The gain is made adjustable at this stage so that the output could be calibrated according to the transducer's capacity used.

The next stage is an analog multiplexer. CMOS differential input analog multiplexer ICs CD 4052 are used to multiplex the differential outputs of the first stage circuits to a common differential amplifier one at a time in sequence. In short, the multiplexer directs the transducer outputs one by one to the input of a common CA 741 based differential amplifier. The gain of the differential amplifier is designed constant since it will be common for all the six transducers. The channel selected for throughput is based on a 3-bit digital control bus fed to the multiplexer. Since the CD 4052 is only a 4-channel multiplexer and six channels are to be multiplexed here, two ICs are cascaded in parallel to offer eight channels. The two least significant bits (LSB) of the control bus, namely; A_0 and A_1, are fed directly to the A and B inputs of both CD 4052s. The most significant bit (MSB) or A_2 of the control bus is wired to the INH input of the first IC. It is inverted using a SL100 switching transistor and fed to the INH input of the second multiplexer IC. In this way the first 4 channels (first CD 4052) or the second 4 channels (second CD 4052) would be activated depending on the MSB (A_2) bit's status. The truth table **(Table 1)** expresses the mode of activation of the cascaded multiplexer.

The six transducers' first stage outputs are connected to the first six channels of the multiplexer, leaving the last two channel inputs

Table 1. Truth Table of the Analog Multiplexer

Control bus status			Control inputs of the first CD4052			Control inputs of the second CD4052			Channel selected
A_2	A_1	A_0	INH	B	A	INH	B	A	
0	0	0	0	0	0	1	(IC inhibited)		1
0	0	1	0	0	1	1	(IC inhibited)		2
0	1	0	0	1	0	1	(IC inhibited)		3
0	1	1	0	1	1	1	(IC inhibited)		4
1	0	0	1	(IC inhibited)		0	0	0	5
1	0	1	1	(IC inhibited)		0	0	1	6
1	1	0	1	(IC inhibited)		0	1	0	7
1	1	1	1	(IC inhibited)		0	1	1	8

Table 2. Forces Measured on a Bent Leg Tool Using the System

		Repl 1		Repl 2		Repl 3	
		Mean	Std dev.	Mean	Std dev.	Mean	Std dev.
Speed 2.0 kph:							
Draft	kN	1.21	0.17	1.18	0.14	1.28	0.17
Vertical force	kN	0.52	0.06	0.60	0.03	0.55	0.04
Lateral force	kN	0.24	0.02	0.19	0.03	0.29	0.02
Speed 4.0 kph:							
Draft	kN	1.40	0.19	1.38	0.17	1.37	0.09
Vertical force	kN	0.67	0.07	0.68	0.05	0.68	0.02
Lateral force	kN	0.27	0.04	0.21	0.05	0.32	0.04

grounded. The multiplexed and amplified output from the common differential amplifier is wired to the Analog to Digital (A/D) converter of the next stage, namely; the digital data logger for sequential logging of data. The digital data logger used was a unit developed in an earlier work (Durairaj, 1992). The 3-bit control bus is derived from the digital data logger's address bus, so that each of the six transducers outputs could be stored one by one in sequence in the data logger's memory. The 7th and the 8th channel zero outputs from the multiplexer are also stored in the logger after each set of 6 sensor outputs and acts as a demarcation between each set of six force data at any chunk of time. A dual power supply rail of +6V, 0, −6V is provided to the above circuit from two serially connected 6V lead acid automotive batteries.

The external clock built around a 555 timer IC is provided to clock the circuit at the required time interval of 0.1 second. This implies that every 0.1 second, one force transducer is scanned and its output recorded. Within 0.8 second one set of force data from all the six transducers would be stored in the logger and so on. The data logger and its power supply are made portable so that it could be separated from the dynamometer and taken to the laboratory for interfacing the logger with a personal computer through a digital I/O interface card (ESA, Bangalore) installed in a free expansion slot. A BASIC program was developed to import data from the logger to a micro computer and to compute the forces acting on the tillage tool. BASIC has direct input/output commands for addressing port addresses of the computer and was hence convenient for the interfacing work.

The Field Experiment

Once fully assembled, the unit was field tested to find its efficiency under actual conditions. Using a 30-hp tractor, tests were carried out on a bent leg tool of 20 cm wide, 30° bend angle and 11.5° rake angle, in a loamy sand soil strip of 20 × 6 m size. The field strip was thoroughly ploughed and rotavated to bring out a uniformly fine tilth. Sprinklers were used to add field moisture of about 17 percent d.b. The field was once again rotavated and rolled using a compacting roller. The cone index was measured at random locations on the strip to check for uniformity of soil strength. The working depth was maintained at 25 cm in all the trials and three replicatory runs were made at each speed of 2.0 and 4.0 kph. The data sampled in each run was logged using the system and imported to a personal computer.

Results and Discussion

Table 2 shows the results of average forces calculated by the computer based on the data collected. Since the selected field strip was of smaller size and its soil condition controlled to 'soil bin' status, the mean forces do not show any marked difference between replications. But the results indicate a clear increase in draft and vertical force requirement for an increase in speed of operation. This demonstrates the efficacy of the system for tillage studies. The system is simple, less costly and is easily built by a needy researcher.

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A Study and Analysis of Energy Consumption Patterns in Tea Factories of South India — For Energy Conservation Solutions

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Abstract

Tea is a major plantation crop in India, being a substantial foreign exchange earner. Moreover, tea plantation also employs tens of thousands of work force accounting as a large employer in rural, hilly regions. In addition, the manufacture of tea is highly energy-intensive process. In this paper, data on the energy usage patterns in 25 tea factories in South India of both CTC and Orthodox (Ortho) types are presented. The variation in energy consumption in kilowatt hour per kg of made tea in the factories based on factors such as type of tea produced, production capacity of factories based on the factors such as type of tea produced, production capacity of factories based on the factors such as type of tea produced, production capacity of factories, climate, etc., are analyzed. The specific energy consumption for the different processes are studied. Broadly, this will help in identifying the areas and methods for energy conservation in tea factories.

Introduction

India is the biggest producer, exporter (220 Mkgs/y) and also the largest consumer of tea in the world. Of the world's output of 2 589 Mkg of tea in 1993, India's share was 29.2% [1]. Black tea (CTC and Ortho) leads to 75% of the global output and the green tea is the rest. In India tea is grown mainly in the North eastern states (76.5%) like Assam, West Bengal and others and in South Indian states (23.5%) like Tamilnadu, Kerala and Karnataka.

Tea manufacture is one of the most energy-intensive agricultural processes. Energy eqivalent to 700 million kgs of coal or its equivalent was spent for the manufacture of tea during 1990 [2]. This is expected to go up to 1 000 million kgs of coal or its equivalent by 2000 AD with increasing tea production.

Tea Process

Black tea processing as a whole consists of drying process and a number of mechanical operations combined with or alternated by chemical and enzymatic reactions [2]. Tea manufacture requires electrical energy to run the machines and thermal energy to reduce water content of the leaves from 75 ± 5% wet basis (w.b) to 3 ± 0.5% (w.b) during various processes. There are two different methods of tea manufacture known as Ortho and CTC. Ortho is the traditional process of tea manufacture wherein the withered leaves are rolled, fermented and dried. In CTC process, withered leaves are subjected to severe crushing, tearing and curling to intensive maceration to ensure rapid and complete fermentation.

The production of tea from green leaves is essentially a gradual oxidation process involving mainly the following stages: withering, rolling, fermentation and drying.

Withering is the first step in the process to prepare the leaves for a correct physical condition for rolling. The harvested tender green leaves (m.c. 75 ± 5% w.b) are spread with a bed thickness of 0.25 ± 0.05 m over wiremesh in specially made wooden troughs. A cross flow of ambient air, during favourable atmospheric conditions or heated air not exceeding 32°C is maintained by an axial electric fan with a specific flow rate of 0.175 ± 0.075 m^3/s per m^2 for the major part of the time. Withering duration is from 16 to 19 hours. Mainly in the Ortho process withering requires 22.5 ± 2.5% of the total fuel used for the entire process.

During rolling the leaf is damaged in such a way that while twist is produced, the semipermeable membrane in the leaf is distorted allowing the contents i.e., juice/sap to be mixed in the presence of air which will initiate the chemical changes needed for black tea production through fermentation. In the South Indian CTC process, pulverized tea dust (from final stage) is added in some factories to adjust moisture content and also to get a strong liquor. The types and number of rollers employed in the CTC and Ortho methods are varied.

The oxidation process reaches its maximum intensity during the fermentation stage. It involves placing rolled leaves on static beds or in slowly rotating drums at room temperature and with increased humidity of 90% using humidifiers whenever necessary. One to two hours are required for CTC and 3 to 4 hours for Ortho for fermentation.

In the final stage the fermented leaves are mostly fed into a Fluidized Bed Dryer at a temperature of 110 ± 10°C in the case of Ortho and 130 ± 20°C in the case of CTC for 10-12 minutes. In a few factories conventional tray dryers are used for drying Ortho tea. During the firing stage, the copper red colour changes to black with a final moisture content of 3 ± 0.5% (w.b). Then the dried product is graded into leaves and dust by sifting and then quickly packed.

Air heating furnaces fed by coal or fuelwood or other fuels are utilized as a source of thermal energy. Heat exchange between hot flue gas and ambient air is obtained through cast iron pipes.

In comparison with total amount of thermal and electrical energy required for manufacture of one kg of made tea, human energy utilized is negligible. The whole process of tea manufacture from collection and spreading of green leaves on through packing of sifted tea makes a duration of about 24 hours. The theoretical thermal energy needed to produce 1 kg of black tea is calculated at 2.7 kWh. Electrical energy depends on the extent of mechanization and method of manufacture.

Review of Early Works

Ramakrishna [3] in his study reports that electrical energy consumption for tea manufacture varies from 0.65 ± 0.15 kWh/kg MT [MT = made tea]. He further reports that in South India electrical energy consumption for CTC is higher than that for Ortho and thermal energy consumption is less for the CTC than that for Ortho. De Silva [4] reports that in the total energy usage 88% is for thermal and the balance for electrical. The average specific electrical and thermal energy being consumed are 0.88 ± 0.12 kWh/kg MT and 5.4 ± 0.9 kWh/kg MT, respectively, in Sri Lanka. Sooriamoorthy and Palaniappan et al. [5] report that about 84 ± 4% thermal energy used is for CTC drying and the remaining for withering in South India. the corresponding value for Ortho tea varies between 70 ± 5%. The lowest specific thermal and electrical energy consumption observed in their studies are 3.75 ± 0.25 kWh/kg MT and 0.53 kWh/kg MT, respectively. Their data analysis for 6 tea factories shows that the average total specific energy consumption for Ortho and CTC are 5.3 ± 1.0 kWh/kg MT and 6.4 ± 1.5 kWh/kg MT, respectively.

Objectives

This study has the following objectives:

a. To present measured data on the energy usage pattern in 25 factories in South India;
b. To analyze the variation in energy consumption in factories based on factors such as type of tea produced, production capacity of factories, climate, etc;
c. To study the specific energy consumption for the section-wise tea manufacture.

Data Collection

For the present study 25 factories situated in different regions (**Table 1**) of South India are classified into three categories depending on their annual tea production:

Table 1. Details of 25 Tea Factories Where Data Were Collected

Region	No. of CTC factories	No. of Orthodox factories	Latitude in degrees	Longitude in degrees	Altitude range	Annual precipitation (mm)
Tamilnadu Tirunelveli	1	1	9N	77E	1000-1200	2000
Tamilnadu Anamalais	5	2	10.5N	77E	1000-1150	2000
Tamilnadu Nilgiris	4	5	11N	77E	1500-2000	1500
Kerala-Idukki	4	1	9.5N	76E	800-1000	3700
Karnataka	2	nil	13N	76E	900-1100	2500

Table 2. Common Energy Conversion

Material	Quantity	Energy Units kWh
Fuelwood	1kg	2.35
Coal (lignite)	1Kg	8.9
Briquette	1kg	5.29
Furnace Oil	1ℓ	9.3
Manday	8h	4.5

Table 3. (Mean of 5 years Data) Specific Thermal Energy (kWh/kg MT) for Large, Medium and Small CTC Factories

Factory	Mean Specific Thermal Energy (kWh/kgMT)
LF1	5.8
LF2	4.03
LF3	9.60
LF4	3.92
LF5	6.07
LF6	5.58
LF7	4.67
LF8	4.85
LF9	5.24
Mean for Large Factory	5.53
MF14	6.98
MF15	7.03
MF16	9.35
MF17	8.16
Mean for Medium Factory	7.95
SF21	6.96
SF22	7.21
SF23	6.82
Mean for Small Factory	7.00

a. Large factories producing ≥ 0.75 Mkg/y - Number of sites chosen - 13 (CTC = 9; ORTH = 4);
b. Medium factories producing 0.5-0.75 Mkg/y - Number of sites chosen - 7 (CTC = 4; ORTH = 3);
c. Small factories producing ≤ 0.5 Mkg/y - Number of sites chosen - 5 (CTC = 3; ORTH = 2).

Data on tea production, quantity of solid/liquid fuel used in furnace on daily or monthly basis, the rainfall details at the site, the electric power used from state grid, captive power generated, cost of fuels, operating parameters in dryer and other relevant details were collected and processed for the above 25 factories. Using the conversion factor shown in **Table 2**, the data were reduced to a common energy unit (i.e.) kWh/kg MT. The mean of five years data month-wise on specific thermal energy and specific electrical energy for the three categories of factories were compiled. The average values of specific thermal and electrical for the 25 factories are presented in **Tables 3**, **4**, **5** and **6**.

By using rainfalls in each factory, the variation of average specific thermal energy for summer, monsoon and winter are presented for CTC and Ortho in **Table 7**.

Table 4. Comparison of Average (Mean of 5 years) Specific Electrical Energy (kWh/kgMT) for Large (LF), Medium (MF) and Small (SF), CTC Factories

Factory	Mean Specific Electrical Energy (kWh/kgMT)
LF1	0.90
LF2	1.10
LF3	0.60
LF4	0.73
LF5	0.64
LF6	0.79
LF7	0.91
LF8	0.88
LF9	0.55
Mean for Large factory	0.79
MF14	0.62
MF15	0.77
MF16	0.65
MF17	0.92
Mean for Medium Factory	0.74
SF21	0.90
SF22	0.64
SF23	1.04
Mean for Small Factory	0.86

Table 5. Comparison of Average (Mean of 5 years) Specific Thermal Energy (kWh/kgMT) for Large (LF), Medium (MF) and Small (SF) Orthodox Factories

Factory	Mean Specific Electrical Energy (kWh/kgMT)
LF10	4.81
LF11	4.06
LF12	4.01
LF13	4.97
Mean for Large Factory	4.46
MF18	6.62
MF19	7.02
MF20	4.76
Mean for Medium Factory	6.13
SF24	7.10
SF25	5.75
Mean for Small Factory	6.43

Table 6. Comparison of Average (Mean of 5 years) Specific Electrical Energy (kWh/kgMT) for Large (LF), Medium (MF) and Small (SF) Orthodox Factories

Factory	Mean Specific Electrical Energy (kWh/kgMT)
LF10	
LF11	0.73
LF12	0.77
LF13	0.79
Mean for Large Factory	0.77
MF18	0.61
MF19	0.62
MF20	0.64
Mean for Medium Factory	0.62
SF24	0.45
SF25	0.97
Mean for Small Factory	0.71

Table 7. Comparison of Mean Values of Seasonal Specific Thermal Energy Consumption of 25 Factories

Factory	Sumer	Monsoon	Winter
LF1	5.11	6.55	5.72
LF2	4.00	4.26	3.84
LF3	8.89	9.87	10.14
LF4	3.84	4.29	3.62
LF5	6.07	5.73	6.24
LF6	5.51	5.61	5.60
LF7	4.38	5.01	4.62
LF8	4.48	5.06	4.97
LF9	4.57	5.42	5.74
LF10	4.54	4.69	5.19
LF11	3.81	4.39	3.99
LF12	4.00	4.37	3.65
LF13	4.32	4.43	6.15
MF14	6.22	8.17	0.54
MF15	7.13	7.56	7.21
MF16	8.70	10.39	8.96
MF17	7.49	9.40	7.61
MF18	6.61	6.51	6.76
MF19	6.80	7.15	7.12
MF20	4.33	5.03	4.91
SF21	6.38	7.73	6.78
SF22	7.29	8.20	6.13
SF23	5.67	8.89	5.89
SF24	6.73	6.73	7.68
SF25	5.04	5.94	6.27

Results on Data Analysis

The average specific thermal energy (STE) for large factories is 5.53 kWh/kg MT with the lowest and highest values as 3.92 and 9.6 kWh/kg MT. The same for electrical energy is 0.78 kWhkg MT with the lowest and highest values as 0.55 and 1.1 kWhkg MT.

The average STE for medium factories is 7.2 kWh/kg MT with the lowest and highest values between 4.76 and 9.35 kWh/kg MT. Electric energy value for medium factories is 0.69 kWh/kg MT with 0.61 and 0.92 kWh/kg MT as the lowest and highest values, respectively.

For small factories the average thermal energy consumption is 6.78 kWh/kg MT with 5.75 and 7.21 kWh/kg MT as the lowest and highest values, respectively. The average electric energy for small factories 0.8 kWh/kg MT with the lowest and highest values as 0.45 and 1.04 kWh/kg MT.

The STE consumption is low in large factories in comparison with medium and small factories.

The average specific electrical energy (SEE) consumption in large factories is lower than in small factories but higher than for medium factories.

It is interesting to observe that the average thermal consumption of two factories, situated in the same region and both producing CTC tea varies by 2.5 times showing imperative reasons to adopt energy conservation measures.

The data clearly indicates that the specific thermal and electric energy consumption for Ortho factories are lower than that for CTC in all cases of large, medium and small factories.

The average thermal consumption for large, medium and small factories varies by season. It is highest during monsoon than winter and summer. The average variation during monsoon and winter comparing with summer for large factories are 20% and 18%, respectively. The same values for medium and small factories are 13%, 3% and 21%, 7%, respectively.

Analyzing the seasonal variation on specific thermal energy consumption for CTC and Ortho factories separately, it is found that CTC has lowest thermal energy consumption in summer, followed by winter and monsoon while for Ortho factories the lowest consumption order is monsoon followed by summer and then winter.

Statistical Analysis

Statistical analysis through ANOVA programme on specific thermal energy and specific electric energy for all the 25 factories have been performed to understand the variations of specific energies and what they depend on.

a) Method of Manufacture
b) Production Capacity
c) Seasons (or) Period of Manufacture (Viz Summer, Winter, Monsoon)

The analysis clearly indicates the following points:

The STE of factories based on method of manufacture, season and production capacity shows a clear variation. The variations of SEE in factories based on method of manufacture and production capacity are significant. But not significant for the seasonal changes.

For large factories the seasonal variation in STE is not significant whatever be the method, though in graphical analysis as explained earlier a slight variation is observed. In the case of medium and small CTC factories the STE values for different period of production are significant. For medium Ortho factories it is not significant. (As only two factories manufacturing Ortho in small category are considered in this study, statistical analysis in STE and SEE for the same has not been done).

Large CTC, large Ortho and small CTC factories show no significant variation in SEE over the seasons. Clear variation is observed in the case of medium CTC factories but it is not so for medium Ortho factories.

Thus a general agreement exists between the statistical anslysis and graphical analysis.

Section-wise Energy Consumption for Tea Manufacture

To study specific energy consumption at different stages of tea processing, energy data were collected from one CTC factory and one Ortho factory. These data were analyzed to study the overall energy consumption in different manufacturing processes, section-wise energy consumption with the capacity utilization.

Daily and monthly coal and electricity consumption in factories were collected. Data were checked by periodic direct measurements. Electrical energy consumption is directly read from energy meters fixed with each section in one CTC factory. In the other factory it is measured using multimeter and Kilowattmeter. Coal consumption for withering and drying were also obtained. Different samples of coal used in the factories were collected and their calorific values were determined using bomb calorimeter.

For the CTC factory which annually produces 0.3 million kgs of sifted tea, section-wise energy consumption is given in **Table 8**. It is observed that 90% of the total energy was thermal energy while 10% was the electrical energy. Withering, cutting-fermentation, drying and sifting consumed 16%, 47%, 26% and 11% of the total electrical energy, respecitively. In CTC factories of South India the hot exhaust air from drier is used for withering mostly.

The Ortho factory under study produced around 1 million kg of sifted tea per annum. The electrical and thermal energy requirements are 0.63 and 5.15 kWh, respectively. The section-wise

Table 8. Section-wise Specific Energy Consumption in a CTC Factory

Section	Electrical Energy kWh/kg MT	Thermal Energy kWh/kg MT	Total Energy kWh/kg MT
Withering			
Cutting-Ferment	0.315	0.000	0.315
Drying	0.174	6.020	6.194
Sorting-Packing	0.074	6.000	
Total	0.67	6.020	6.690

Table 9. Section-wise Specific Energy Consumption in an Orthodox Factory

Section	Electrical Energy kWh/kg MT	Thermal Energy kWh/kg MT	Total Energy kWh/kg MT
Withering	0.22	1.29	1.51
Cutting-Ferment	0.189	0.00	0.189
Drying	0.126	3.86	3.986
Sorting-Packing	0.095	0.00	0.095
Total	0.63	5.15	5.78

energy consumption in the Ortho factory is given in **Table 9**. In the total energy 89% was thermal energy while 11% was electrical energy. Withering, rolling, fermentation, drying and sifting consumed 45%, 30%, 20% and 15% of the total electrical energy, respectively.

A comparison of specific thermal energy and specific electrical energy consumption for CTC factory and an Ortho factory reveals that STE and SEE for a CTC factory are higher than those for an Ortho factory.

Conclusion

On analyzing the 5 years energy consumption data for 25 tea factories in South India, the following conclusions emerged (**Table 10**). The average specific thermal energy consumption is lower in large tea factories in comparison with medium and small factories. Similarly, the average specific thermal and electrical energy for CTC factories are higher than those of Ortho in all categories of factories. There is seasonal variation in energy consumption.

The variation on specific electrical energy of factories over seasons is not significant. For medium CTC factories variation in specific thermal energy and specific thermal energy is significant. It is also noted that two factories situated in same region and producing similar type tea have a variation in average energy consumption to the extent of 2.5 times. This underlines the need to introduce energy conservation measures in tea factories.

The study on section-wise energy consumption shows that the CTC method consumed more electrical and thermal energy than those for the Ortho method. In tea manufacture the specific thermal energy is dominant over the specific electrical energy to an extent of nine times.

Table 10.

Type of Tea Factories	Average Specific Thermal kWh/kg MT	Average Specific Electrical kWh/kg MT
CTC-LF	5.53	0.79
CTC-MF	7.95	0.74
CTC-SF	7.00	0.86
ORTHO-LF	4.46	0.77
ORTHO-MF	6.13	0.62
ORTHO-SF	6.43	0.71

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Energy Utilization in Fruit Production in Chile

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Abstract

The objective of this research work was to analyze the utilization of energy in the production of fruits in Chile in order to improve the efficiency of its use.

The field work was carried out in the Vth, Metropolitan, VIth, VIIth and VIIIth Region between 1992 and 1995, working with 187 producers of table- and wine-making grapes, raspberry, orange, lemon, plum, pear and apple. Treatments comparing varieties, tree density, orchard size and irrigated/dryland were used in a completely randomized design. As energy efficiency indicators the net energy gain, output/input relation, and the unit cost (MJ/kg) were used.

The results showed costs from the range 32-40 GJ/ha in dryland grapes and oranges to 55-65 GJ/ha in irrigated grapes and apples; nitrogen and fuel accounted for the largest share of the cost adding up to more than 50% of the total cost. The O/I relation ranged from a low of 0.44-0.58 in raspberry to a high of 2.14-2.22 in red apples; the unitary cost ranged from 1.06-1.10 MJ/kg in red apples to 4.40-6.41 MJ/kg in raspberry.

[1] Project 92.23.16-1, financed by the Research Division of the University of Concepcion, Chile.

Acknowledgements: Thanks are due to the agricultural engineering students: Miguel Martinez, Roberto Millán, Stanley Best, Alejandro Farias, Marcelo Retamal, Duilio Pruzzo, Alexis Calabrán and Edecio Neira who carried out the field work, and to the fruit producers that allowed us the use of their orchards' production data. The author is also indebted to the Research Division of the University of Concepcion which financed this work through Project 92.23.16-1.

Introduction

The increasing use of energy resources, mainly of the non-renewable type, has been closely associated with the progress and well being of humanity. Consequently, man that 100 000 years ago used only 8.4 MJ/person-day is utilizing today more than 1 200 MJ/person-day in the industrialized countries of the West (Fluck, 1992; Stout, 1990; CNE, 1993).

In agriculture the intensive use of high energy inputs (fertilizers, fuel and biocides) has made it possible to greatly increase the yields of most crops; however, Pimentel (1980), has demonstrated that the energy efficiency of maize, measured by the output/input relation, decreased from 3.70 to 2.47 between 1945 and 1980.

In Chile it has been established that commercial agriculture of annual crops is highly dependent on imported energy inputs. This situation should be a warning to a country that is already importing 90% of the fuel for vehicles that they utilize (Hetz, 1992; CNE, 1993; SNA/CAS, 1995).

Fruit production is very important in Chile; over a planted area of 200 000 ha it generates exports for about US$1 000 million annually (CIREN/CORFO, 1995; SNA/CAS, 1995). The most important fruit species are grapes (*Vitis vinifera* L), apples (*Malus sylvestris* M), pears (*Pyrus communis* L), plums (*Prunus salicina* L), oranges (*Citrus sinensis* (L) Osbeck), lemon (*Citrus limon* (L), Burm) and raspberry (*Rubus idaeus* L), which together add up to 65% of the planted area. The importance of this sector of the economy will grow in the next decade because there is a large area with orchards not yet in full production.

Consequently, with what has been presented as the main objective of this research work was to analyze the utilization of energy in fruit production in Chile in order to improve the efficiency of its use.

Methodology

The field work was carried out between 1992 and 1995 in the Vth, Metropolitan, VIth, VIIth and VIIIth Region of Chile. This zone is located between parallels 32° to 38° latitude South; it serves as a North/South axis meridian 71° longitude West. It has soils of classes I, II, III and IV with irrigation, of aluvial origin, with moderate and heavy textures with good drainage; the rainfall increases from the North (130 mm/year) to the South (1 100

Table 1. Energy Equivalences of Inputs and Products

Inputs	Equivalences MJ/unit	References
Man journey	18.2	Stout, 1990
Woman journey	12.1	Calculated
Animal journey	95.1	Stout, 1990
Diesel fuel, L	47.8	Fluck, 1992
Gasoline, L	42.3	Fluck, 1992
Butane, L	32.3	Fluck, 1992
Electricity, kWh	12.0	Fluck, 1992
Transport by truck, ton-km	3.5	Fluck, 1992
Vine plant	0.4	Calculated
Raspberry plant	0.4	Calculated
Orange tree plant	2.0	Calculated
Lemon tree plant	2.0	Calculated.
Japanese plum tree plant	0.53	Calculated
Pear tree plant	0.4	Calculated
Apple tree plant	0.4	Calculated
1 kg of:*		
Tractor	109.0	Fluck, 1992
Plow	66.8	Fluck, 1992
Subsoiler	66.8	Fluck, 1992
Harrow	64.0	Fluck, 1992
Land leveller	64.0	Fluck, 1992
Post-hole digger	66.8	Fluck, 1992
Fertilizer	64.2	Fluck, 1992
Sprayer/Fogger	62.3	Fluck, 1992
Shoulder sprayer	62.3	Fluck, 1992
Transport wagon	55.4	Fluck, 1992
Vine shoots shredder	64.0	Stout, 1990
Iron	46.4	Stout, 1990
Aluminum	262.0	Stout, 1990
Plastic	9.5	Stout, 1990
Wood/poles	18.9	Stout, 1990
Prunned wood/vine shoots	16.5	Stout, 1990
N-urea	69.0	Fluck, 1992
N-Chilean nitrate	21.1	Hetz, 1992
P_2O_5	14.2	Fluck, 1992
K_2O	9.6	Fluck, 1992
Sulphur	111.4	Stout, 1990
Potassium sulfate	1.6	Fluck, 1992
Muriate of potash	4.5	Fluck, 1992
Glyphosate	452.5	Fluck, 1992
Paraquat	458.4	Fluck, 1992
Carbaryl	152.5	Fluck, 1992
Diazinon	184.7	Fluck, 1992
Captan	114.6	Fluck, 1992
Banvel	295.0	Fluck, 1992
Parathion	160.0	Fluck, 1992
Gyberelic acid	414.6	Fluck, 1992
2,4-D	101.3	Fluck, 1992
Wire, nails	1.0	Fluck, 1992
Paper, carton	9.2	Fluck, 1992
Nylon	60.0	Pimentel, 1980
PVC	120.0	Pimentel, 1980
Sugar	16.5	Pimentel, 1980
Raspberry	2.4	Pimentel, 1980
Table grape	2.85	Pimentel, 1980
Grape, cv. Pais	3.10	Calculated
Grape, cv. Riesling	2.70	Calculated
Oil from grape seeds	40.0	Laboratory
Orange	2.05	Laboratory
Lemon	1.87	Laboratory
Plum	2.20	Pimentel, 1980
Pear	2.55	Pimentel, 1980
Apple	2.35	Pimentel, 1980

* In the case of machines it includes the energy sequestered in the raw materials, the manufacturing process and transport to Chile. For the chemical products the equivalence is per kg of active ingredient.

mm/year).

Work was carried out with a total of 187 producers of: table grape in the Aconcagua Valley (36); table grape (including postharvest operations) in the province of Colchagua (27); raspberry in the provinces of Ñuble (15) and Bío-Bío (8); orange in Cachapoal (21); lemon in Melipilla (10); plum in Maipo (21); and pear (21) and apple (28) in the province of Curico. For the wine-making grapes, advantage was taken of the large amount of information produced by the Research Station of the Ministry of Agriculture at Cauquenes. The producers were randomly selected from lists made available by the exporting enterprises.

Initially, the most representative produciton systems for each specie were identified; then all inputs and outputs to and from the system were identified and quantified; later they were transformed into energy units using the equivalences found in the literature, calculated or established in the laboratory and shown in **Table 1** (Fluck, 1992; Stout, 1990).

Table 2. Variables Studied in Each Fruit Species

Species	Conditions of the experiment
Table grape	Aconcagua. Until harvest; Thompson, Flame and Ribier varieties; 3 planted area ranges: <5 ha, 5-15 ha, >15 ha. Vineyards with 6 to 25 years. Completely Randomized Design, 3 × 3 × 4 factorial.
Table grape	Colchagua. It includes postharvest; Thompson, Flame and Ruby varieties; 3 planted area ranges: <5 ha, 5-10 ha, >10 ha, Vineyards with 6 to 25 years. Completely Randomized Design, 3 × 3 × 3 factorial.
Wine-making grapes	Cauquenes. Varieties Pais in dryland and free conduction, and Riesling with drip irrigation conducted in Double Cross. Vineyards with 6 to 25 years. It includes oil from the seeds.
Raspberry	Ñuble and Bio-Bio. Heritage (two flowers) and Meeker (one flower) varieties conducted in an Inverted Lorena Cross system. Orchards with more than 3 years. Completely Randomized Design with different number of replications.
Orange	Cachapoal. Thompson, Late Valencia and Washington Navel varieties. Orchards with 12 to 25 years. Completely Randomized Design with 3 treatments (varieties) and 7 replications.
Lemon	Melipilla. Genova variety. Ten orchards of 5 to 15 ha and 10 to 18 years of age; t test to compare its mean with that of the oranges.
Plum	Maipo. Three plantation densities: <300 trees/ha, 300-600 trees/ha and >600 trees/ha. Orchards with 7 to 18 years. Completely Randomized Design with 3 treatments (densities) and 7 replications.
Pear	Curico. Packam's Triumph, Beurre Bosc and Red Sensation varieties. Orchards with 7 to 15 years. Completely Randomized Design with 3 teatments (varieties) and 7 replications.
Apple	Curico. Red and green varieties. Three plantation densities: <300 trees/ha, 300-600 trees/ha and >600 trees/ha. Orchards with 6 to 15 years. Completely Randomized Design for reds and t test to compare green with reds.

The energy necessary to carry out each one of the mechanized operations was calculated using the methodology proposed by Bridges and Smith (1979); this methodology, that initially determines MJ/h, adds up the energy costs of machinery manufacturing, fuel, lubricants, filters, repairs, maintenance, operator(s) and relates them with the equipment's effective field capacity (h/ha) to end up with a cost in MJ/ha (Fluck, 1992; Pimentel, 1980).

The energy sequestered in one plant of each specie was established using the information

Table 3. Energy Utilization in Fruit Production, Chile

Specie		Energy Utilization Parameters						
		Input	Largest inputs		Output	Energy efficiency		
		GJ/ha	Item	%	GJ/ha	X NEG (GJ/ha)	O/I	MJ/kq
Table grape,	Ac, uh	54.3-60.6	N-E-F-S	86.2	58.7-77.8	9.6	1.02-1.45	2.01-2.88
Table grape,	Co, ec	73.4-81.6	F-Pm-E-B	66.4	55.5-59.5	−19.5	0.72-0.79	3.63-3.96
Wine grape,	Cq, D	37.5	NK-S-E-P	92.8	23.1-25.2	−12.2	0.58-0.63	4.88-5.34
Wine grape,	Cq, I	63.9	NK-S-E-I	82.7	46.1-50.8	−13.2	0.69-0.76	3.53-3.92
Raspberry,	Ñ-Bi	51.4-60.5	L-F-N-E	87.5	25.7-29.3	−26.6	0.44-0.58	4.40-6.41
Orange,	Ca	32.7-40.2	N-F-Bo-M	83.2	49.3-54.4	14.5	1.32-1.53	1.36-1.56
Lemon,	MR	42.9	N-F-Bo-M	80.0	58.7	15.8	1.36	1.40
Plum,	MR	41.6-55.6	N-F-In-E	84.6	32.1-45.3	−11.7	0.72-0.81	2.70-3.10
Pear,	Cu	48.7-61.4	F-N-B-M	91.6	63.4-115.0	29.6	1.33-1.91	1.36-1.97
Apple red,	Cu	42.8-52.3	Bp-F-N-M	74.8	95.0-114.6	55.1	2.14-2.22	1.06-1.10
Apple green,	Cu	64.6	N-Bp-F-M	81.1	127.1	62.5	1.97	1.19

Nomenclature

NEG = Net Energy Gain ; O/I = Output/Input

Ac = Aconcagua ; uh = until harvest ; Co = Colchagua ; ec = entering cold ; D = Dryland
Cq = Cauquenes ; Ñ-Bi = Ñuble-BíoBío ; Ca = Cachapoal ; MR = Metrop. Region ; I = Irrigated
N = Nitrogen ; E = Establishment ; F = Fuel ; S = Sulphur ; Cu = Curicó
B = Biocioes ; NK = Nitrog.+Potas. ; P = P205 ; L = Labour ; Pm = Packing material
M = Machines ; In = Insecticides ; Bp = Branch props ; Bo = Biocide oil ;

provided by the respective nurseries; the energy needed to bring an orchard from establishment to full produciton was also calculated using the technical coefficients proposed by Harris et al (1990). This energy was distributed in the useful life of each orchard in order to establish an annual cost to add up to the other annual inputs to the system during the period of full production.

The frontiers of the analyzed system corresponded to the primary production in the farm and the transport to the packing plant, without including the energy costs of selection, packing, cold storage and transportation to the shipping port. An exception was table grape in Colchagua which included post harvest operations up to entering cold storage.

As energy efficiency indicators, the Net Energy Gain (NEG) equals Output-Input, the relation Output/Input (O/I) and the energy needed to produce 1 kg of fruit (MJ/kg), were used. For each specie that was studied an appropriate experimental design was used in order to statistically analyze the results; this information and other relevant ones to each specific situation are presented in **Table 2**.

Results and Discussion

In **Table 3** a summary of all results obtained during the 5 years of research is presented. It is possible to see there that the largest energy costs corresponded to table grapes and apples (54-64 GJ/ha), and the smallest to wine-making grapes in dryland and lemon (37-43). Special cases were table grapes in Colchagua with an average Input of 77.5 GJ/ha of which 25.4% corresponded to post harvest operations, and wine-making grapes with drip irrigation with a cost of 63.9 GJ/ha of which 13.2% corresponded to the irrigation system.

These results find an explanation, in the case of table grapes and apples, in the need to produce high quality fruit for exportation which mandates the intensive use of inputs. On one hand, drying wine-making grapes and lemon are produced with low technology systems that do not demand large quantities of inputs. these energy costs are, in general, smaller than the ones established in developed countries (Pimentel, 1980; Pellizzi, 1992). The statistical analysis of the results show that large and high density orchards used more energy than small and low density orchards.

On the other hand, in the large majority of the analyzed species nitrogen and fuel accounted for more than 50% of the total cost, in a similar way as was found in the annual crops (Hetz, 1992; Ahmad, 1994). Other inputs that represented a large cost, depending on the specie, were orchard establishment, sulphur, labour in raspberry and branch props to hold the load of apples; when the 4 major costs are added up values between 75 and 93% of the total are obtained. In **Tables 4** and **5** the partial energy costs for the two most important fruit species, table grapes and apples, are shown in detail to illustrate the distribution of the costs among the different inputs. These results emphasize the importance of rational fertilization according to the soil and foliar analysis and the needs of the trees, and the efficient use of tractors (Fluck, 1992; Stout, 1990; Pimentel, 1980; Westwood, 1982).

In **Table 3** it is also shown that the output ranged from 23-25 GJ/ha in plums to more than 125 GJ/ha in green apples; these yields are, in general, larger than the ones obtained in the majority of other countries and show the high levels of production reached in Chilean commercial agriculture (SNA/CAS, 1995).

The energy efficiency indicators, last 3 columns of **Table 3**, show that apple orchards achieved high values of NEG (55.1-62.5 MJ/ha), and that some species (raspberry, grapes and plums) presented a negative balance for the NEG (−11.7 to −26.6 MJ/ha); This tendency is similar to what has been established in USA (Pimentel, 1980) and Italy

Table 4. Partial Energy Costs in Table Grape Production, Aconcagua Valley, Chile (Unit: MS/ha)

Input	Variety			Average	
	Ribier	Thompson	Flame	MJ/ha	Percent
Nitrogen	13608	18883	17770	16754	29.1
Establishment	11984	11984	11984	11984	20.8
Fuel	11367	11911	12067	11782	20.4
Sulphur	8937	7742	10758	9146	15.9
Labour	2945	2531	2552	2676	4.6
Machinery	1125	1203	1364	1231	2.1
Fungicides	1229	1085	1063	1126	2.0
Insecticides	972	911	986	955	1.7
Potassium	630	671	630	644	1.1
Herbicides	643	494	617	585	1.0
Transport	553	218	330	366	0.7
Boxes	292	280	305	292	0.5
Hormones	—	136	100	79	0.1
Total	54285	58049	60526	57620	100.0

Table 5. Partial Energy Costs in Apple Production, Curico, Chile (Unit: MJ/ha)

Input	Density			Average	
	High	Medium	Low	MJ/ha	Percent
Branch props	9688	10068	11908	10555	22.6
Fuel	11882	10448	9150	10493	22.5
Nitrogen	11123	9255	6188	8855	19.0
Machinery	5904	4697	4546	5049	10.8
Transport	4305	2336	2808	3150	6.8
Labour	2946	2739	2647	2777	6.0
Insecticide	3237	1863	2807	2636	5.7
Fungicide	1792	1821	1643	1752	3.8
Herbicide	1461	1187	1036	1228	2.6
Other fertilizer	7	266	58	110	0.2
Total	52345	44680	42791	46605	100.0

(Pellizzi, 1992), but the figures are different given the different production conditions (Westwood, 1982).

The O/I relation was very low in raspberry (0.44-0.58) and high in apples (1.97-2.22) and pear (1.33-1.91); these results also follow the same tendencies found in USA and Italy. The unit cost showed the same tendencies of the O/I relation, having a low cost for apples with values slightly over 1 MJ/kg, and a high cost the raspberries with values in the range 4.40-6.41 MJ/kg and wine-making grapes with values in the range 3.53-5.34 MJ/kg.

The statistical analysis of the energy efficiency indicators shows the following main results: in table grapes, variety Ribier was the best and no differences were found among orchard sizes; in raspberry, no differences were found between Heritage and Meeker varieties nor between the Ñuble and Bio-Bio provinces; in orange, variety Washington Navel was the best and no differences were found in the comparison with lemon; in plums, no differences were found among the three plantation densities; in pear, variety Packam's Triumph was better than Beurre Bosc and Red Sensation; in apples, high density was better than medium and low in relation to NEG but not in relation to O/I and unit cost (MJ/kg), and green apples were better than reds in NEG but the opposite was true for the O/I relation and unitary cost.

The energy efficiency indicators improved noticeably in some species when by-products are included in the output, such as the wood from prunned branches as solid fuel and the oil from seeds in wine-making grapes.

Conclusions

High energy production costs were found in grapes, apples and pears for which the most important ones are the nitrogen fertilizer and fuel, which added up to more than 50% of the total cost. Other important costs were orchard establishment for grapes, raspberry and plums; labour for raspberry; and branch props to hold the load of apples. Large and high density orchards had a greater cost than small- and low-density orchards.

The energy efficiency indicators show that the most efficient species were apples and the pears with high NEGs (30-60 MJ/ha) and O/I relations (around 2), and low unit costs (around 1 MJ/kg). On the other hand, the most inefficient specie was raspberry with a negative balance as NEG (−26.6 MJ/ha), low O/I relation (around 0.5) and a high unitary cost (4.4 to 6.4 MJ/kg). Some varieties of table grapes, oranges and pears were more energy efficient than others; only in red apples high-density plantation was better than medium and low; no difference in energy efficiency was found among the orchard sizes.

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Prospects of Adapting Gasification Technology in Pakistan

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Abstract

The technology to use agricultural wastes as an alternate source of energy is quite old. Direct burning and conversion of gaseous fuels from solid agricultural wastes are quite common. Agricultural wastes in Pakistan have the potential to produce over 3 million tones of oil equivalent (tOE) which account for about 10% of the total energy demand in the country. Electric power generated from agricultural wastes has been reported to cost 20% to 45% less as compared to conventional thermal power electricity. The cost of electric power generated from rice husk has been valued at Rs. 1.11/kWh.

This paper presents a detailed discussion of the current status of gasification technology. Some of the factors which have been discussed in detail include energy need of the country, energy potentials of the agricultural wastes and design potentials for rice husk fired gasifiers to generate electricity.

Introduction

Energy (defined as potential ability of materials to produce work and/or heat) is normally obtained from two sources:

i) Conventioanl or commercial energy sources such as fossil fuels (coal, fuel oils, LDO, HSD, natural gases) nuclear energy and wood; and
ii) Non-conventional or non-commercial energy sources, including solar, wind, geothermal, sea/tidal waves, agricultural/forestry residues and biomass.

In Pakistan electric energy is produced from hydel (49.1%), thermal (50.8%) and nuclear (0.01%) power generating systems (Energy Year Book 1989). Hydropower is a cheap source of electric energy but the same cannot be produced at any desired location. Most of the hydro-power generated in the country originates from Mangla, Tarbela and Warsak Dams. The transmission of this hydro electric energy to distant places is very expensive. Thermal electric power generation, on the other hand, has the advantage of being produced at any desired location but becomes too expensive if fuel and its transportation costs are high.

Biomass (agricultural, forestry and other vegetative residues) have been used as a source of fuel since mankind discovered fire. Energy from biomass can be obtained either by direct burning (combustion) or by indirect extraction/conversion of fuel gases (gasification/fermentation). Direct combustion which normally uses atmospheric oxygen as oxidant produces carbon dioxide (CO_2) along with heat energy. Increase in carbon dioxide in the atmosphere has caused greenhouse and global warming effects. If the combustion is not complete, carbon monoxide (CO), aldehydes and ketone are produced beside heat generation.

Gasification is physio-chemical process in which chemical changes occur with the transformation of energy. This process produces low BTU gases from incomplete combustion of the biomass. The purpose of gasification is to obtain combustible components, i.e., carbon monoxide, hydrogen (H_2) and methane (CH_4). Fuel gases such as biogas are generally produced as a result of bacterial fermentation of the biomass that is high in organic matter.

The gases produced as a result of biomass gasification or fermentation can be burned directly or used as gaseous fuel for internal combustion engine.

Statement of the Problem

Traditionally, food, shelter and fibre are considered the basic needs of mankind. With the passage of time, energy has become the fourth pre-requisite. Energy demand in any country depends upon three factors as: population and its standard of living; level of industrialization; and level of mechanization in agriculture transport equipment, etc.

The population growth in Pakistan is over 3% and is currently estimated at about 110 million. With this increase in population, the establishment of industries at an accelerated rate and adaptation of luxurious and comfortable lifestyle, the energy needs have forced the government and non-government organizations (NGOs) to loook for alternate energy sources to produce electric energy to meet the increasing demand.

It has been reported (FAO, 1990) that more than 75% energy needs in rural areas in developing countries are met through non-commercial fuel sources such as wood, cowdung and biomass. The energy demand pressure is wiping out Pakistan's limited forest reserves which are probably lowest in the world with a reported 3.5% of total land area (Ramsay, 1985). Deforestation has resulted in rapid degradation/hazards of the environment, including soil erosion and fatal land slides.

Pakistan produces almost every thing for domestic use and is a well known exporter of cotton and rice. During the past, the use of biomass as source of energy was limited to direct combustion for domestic as well as industrial use and generation of biogas through fermentation on a limited scale. Some agricultural wastes such as rice straw and rice husk (due to their bulkiness) are not easy to store and transport. As such they are not very popular even for direct combustion. Some alternate technologies have been developed and are now commercially available which can make use of these agricultural waste products to regenerate energy.

Objectives

The specific objectives of this study were:

i) To assess the availability of agricultural wastes, specially rice straw and rice husk;
ii) To estimate the potential of energy available from agricultural wastes;
iii) To identify areas of research in order to assess the suitability of available commercial technologies to convert agricultural wastes to energy under agro-climatic conditions; and
iv) To make sound recommendations to set up village-level electric generating power units using agricultural wastes with special reference to their economic feasibility.

Energy Budget of Pakistan

It has been reported (Pakistan Agricuture, 1990) that in Pakistan the highest rate of growth for energy consumption is for domestic use which has been estimated at 13% of the total since 1975-76. The per capita consumption of electric power in the country is still very low. The total energy consumption in Pakistan is 30 million tones of oil equivalent (tOE) with an average per capita consumption of 272 kgOE as compared to 8 000 kgOE in the USA (Energy Yearbook, 1989). The same publication projects the demand for energy in the country at 680 kgOE by the end of century. This indicates that the country is faced with an acute shortage of energy resources if the same are not met partially by some alternate means, including biomass.

Assessment of Energy Production Potential from Agricultural Wastes

There are numerous sources of agricultural wastes such as wheat straw, rice straw, rice husk, maize cobs and stalks, barley straw, sugarcane stripping, cotton stalks, wines and residues of pulses, grams, soybean, potatoes, groundnut and residues of other oil-seed crops.

Wheat straw is rich in nutrients, hence the most popular cattle feed in Pakistan, hence not adviseable to use it as source of fuel. Only three major agricultural wastes (or by-products: cotton stalk, rice straw and rice husk) which are already being used as fuel in domestic as well as industrial sectors are be considered in assessing their potentials for energy production.

The production of these crops and the estimated volume of their by-products are shown in **Table 1**.

The total energy potential from the above mentioned by-products or agricultural wastes is shown in **Table 2**.

During 1988-89, the total energy consumption in Pakistan was estimated at over 30 million tOE. **Table 1** shows that the country's

Table 1. Selected Crop Production and Estimated By-products*.

Year	Cotton Seed	Rice Grain	Cotton[a] stalk	Rice[b] straw	Rice[c] husk
1986	1 220	2 919	2 440	4 379	876
1987	1 322	3 486	2 644	5 229	1 046
1988	1 472	3 241	2 944	4 862	972
1989	1 430	3 200	2 860	4 800	960
1990	1 460	3 220	2 920	4 830	966
Average	1 381	3 213	2 760	4 820	964

[a] Cotton stalk = 200% of seed cotton production.
[b] Rice straw = 150% of rice production.
[c] Rice husk = 30% of rice production.
*Agricultural Crops. 1990 (1 000 mt).

Table 2. Total Energy Potential from By-products

By-product	Annual Waste (000 tons)	Calorific Value (kJ/kg)	Energy Potential	
			10^{13} kJ	10^6 tOE
Cotton stalk	2 760	15 800	4.36	1.04
Rice straw	4 820	15 000	7.23	1.73
Rice husk	964	15 500	1.49	0.36
Total	8 554	—	13.08	3.13

Note: 1 kg oil equivalent (1 kgOE) = 41 868 kJ.

agricultural wastes or by-products from the three selected major crops has the potential to meet 10% of the national energy demand. The utilization of these by-products depends upon their efficient collection, storage, transportation, system losses and other domestic/industrial uses. It is, therefore, assumed that the recovery or utilization of these agricultural wastes will not be more than 50%, i.e., usable wastes energy potential will be about 1.57 million tOE.

Based on the above analysis, it is safe to say that about 1.5 million tOE of national energy demand (5% of the total) can easily be met by using agricultural wastes from cotton and rice alone. Again, assuming an overall 50% efficiency of electric generation from the power plants using agricultural wastes as source of fuel, the energy potential to produce electric power will be approximately (1.75 million tOE × 0.5 × 11.63 MWh/tOE) 9.13 million MWh (1 tOE = 11.63 MWh).

Rice Straw-based Technology

Rice straw has several uses at the farm and in the industry. Some of these are: cattle feed; domestic and industrial fuels; and raw material for packages industries.

Due to very low specific weight (122 to 145 kg/m^3), rice straw storage and transportation does not leave it competitive with other types of biomasses such as woodchips and fuel wood. Cattle also eat it as a last resort. Due to these reasons it has been observed that some farmers in remote areas burn their rice straw to get rid of it.

The commercial use of rice straw has been to burn it directly in the steam boiler furnaces, especially in rice mills which are used to drive steam turbines coupled with electric generators to produce electricity.

Rice Straw as Fuel to Generate Electric Power

Rice straw (due to its low specific weight) is first densified and baled using hydraulic presses. Specially-designed bales handling equipment and burning furnaces are used to produce steam in the boilers. This steam is then used to run the steam turbines coupled with electric generators. Since electricity is generated thermally, all the conventional requirements for installing such units are applicable, specially water supply source for steam production and cooling purpose.

India has established this kind of plant which uses rice straw as fuel to generate electricity and its cost has been reported to be Rs. 2.08/kWh. The total potential of electric power generation using rice straw in Pakistan is estimated at (1.73 ÷ 4 million tOE * 11.63 MWh/tOE), approximately 5 million MWh using 50% recovery and 50% system efficiency.

An alternate way of using rice straw as source of fuel is to first chop it and then make briquettes. Briquettes are high-density biomasses formed by compressed (up to 100 MPa) biomass using various kinds of presses of up to 100 MPa capacity. The use of briquettes as fuel in the gasifier increases its efficiency and higher calorific value of producer gases, as due to high bulk density, residence time is higher. The Agricultural Development Bank of Pakistan has a project profile to finance such projects. One such plant is already functioning near Mardan which makes briquettes from saw dust. M/S Progressive Carbon Enterprises Ltd., Lahore has established an industrial unit which uses rice straw to produce activated carbon (used as adsorbent in edible oil mills), pyrolysis oil (used as furnace oil), charcoal briquettes (used as a smokeless domestic fuel for outdoor picnic cooking) and producer gasses (used as fuel gas).

The problem associated with using rice straw as source of fuel is its high ash content which has been reported to be around 15%.

Rice Husk as Fuel to Generate Electric Power

Rice husk-based technology to generate electric power is more popular in rice producing countries of the world: Peoples Republic of China (PRC), India, Philippines, Thailand, Malaysia, Sri Lanka and Vietnam. PRC is perhaps the pioneer in this technology with more than 40 years of R&D experience. The FAO of the UN has established a program to coordinate R&D, technology transfer and promotion through its Rice Husk Gasification Network under UNDP. PRC is commercially producing and exporting 160 kW and 60 kW electric generation plants fueled with rice husk.

Rice husk has been reported to contain high silica content (which is directly related to soil and plant characteristics). Higher silica contents beside ash problems may result in sintering and slag forma-

APPENDIX Cost Analysis of A 50 kW Rice Husk Gasifier Based Electric Power Generation System

A. Fixed Cost	
Cost of gasifier @ Rs 2 500/kW	= Rs 125 000.00
Cost of Diesel electric generator @ Rs 3 000/kW	= Rs 150 000.00
Total capital cost (P)	= Rs 275 000.00
Salvage value (S) @ 10% of P	= Rs 27 500.00
Expected life (L)	= 8 years
Annual use	= 2 000 h
Nominal interest rate	= 11%
Prevailing inflation rate	= 8%
Real rate of interest (I_r)	$= \frac{0.11 - 0.08}{1 + 0.08} = 2.78\%$
Cost of assets (C) = P – S	= Rs 247 500.00
Capital recovery with return	$= \frac{CI_r(1 + I_r)^L}{(1 + I_r)^L - 1}$
	= Rs 53 684.00/year
	= Rs 26.85/h
Taxes, shelter & insurance @ 2% of P	= 0.02*P
	= 0.02*275 000
	= Rs 5 500.00/year
	= Rs 2.75/h
Total fixed cost	= 26.85 + 2.75
	= Rs 29.60/h
B. Variable Cost	
Repair & Maintenance cost (R&M) @ 5% of P	= Rs 3.13/h
Cost of Rice husk (assuming free)	= Rs 0.00
Cost of HSD (20% HSD, 80% gas) @ 12 L/h and Rs 5.25/L (F)	= Rs 12.60/h
Labour cost (L)	= Rs 10.00/h
	= R&M + F + L
Total variable cost = 3.13 + 12.60 + 10	= 25.73
C. Cost of Operation	
(Fixed Cost + Variable Cost) = 29.60 + 25.73	= Rs 55.35/h
D. Cost of Electric Generation	
Diesel Engine Power	= 55 kW
Electric generation output @ 90% efficiency	= 50 kW
Cost of electric generation	= 55.35/50
	= Rs 1.11/kWh

tion if the gasifier temperature exceeds 1 100°C and my cause combustion problems and blockage of air and gas supply ducts. The use of rice husk briquettes have been reported to have 20% increase in system efficiency (Eriksson and Prior, 1990).

Need for R&D in Rice Husk Gasification

Pakistan is perhaps the latest country to enter the business of gasification of rice husk-based power generating systems although a limited research work has been carried out in the country by the University of Engineering and Technology. However, coordinated R&D is still lacking.

In the preparation of this report, many assumptions have been made due to non-availability of statistical data. In order to promote this technology, a comprehensive R&D schedule has to be prepared by a team of experts. Some of the guidelines for R&D are summarized as follows:

i) Development of appropriate rice varieites with low ash and silica contents;
ii) Development of design parameters for a low-cost and efficient gasification system;
iii) Test and evaluation of various gasification systems to assess their relative performance;
iv) Development of a data base containing information about production of agricultural wastes and their conventional uses; and
v) Evaluation and feasibility study of different agricultural wastes for their use as gasification fuel.

Cost of Electric Generation

Cost of thermal electric power generation in Pakistan is about Rs. 1.15/kWh (Appendix). Rice husk- and rice straw-based systems to produce electric power have been reported to be 20%-45% cheaper.

Conclusion and Recommendations

Based on the information collected and literature surveyed, it has been found that by-products on agricultural wastes (rice straw and rice husk) have reasonable potentials to produce electric power using direct combustion and by producing gaseous fuels by gasification. Accordingly, the following recommendations are presented for a successful introduction and tapping these natural resources to generate electrical power.

i) Pakistan should immediately officially join the FAO's Rice Husk Gasification Network.
ii) NGOs/consultants should be hired for detailed feasibility studies and popularization of this technology.
iii) Appropriate design parameters for economical gasifiers need to be developed.
iv) Availability and potential of various agricultural wastes to generate electric power should be established.
v) Integrated rural electric energy plan needs to be developed in order to utilize locally-produced electric power based on agricultural wastes as fuel.
vi) Economic feasibility studies need to be carried out using experimental gasifiers.
vii) Gasifiers need to be imported from PRC through FAO for their evaluation and adaptation.
viii) Technology needs to be demonstrated in the selected areas to ascertain their suitability under local conditions.

(Continued on page 28)

Development of Low-volume Spinning Brush Pesticide Applicator


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Abstract

A manually-operated spinning brush low volume pesticide applicator was designed, developed and tested in the laboratory for its performance. Two types of brushes, namely; vegetable fibre brush and nylon brush were used during the test. It was found that at 33 mℓ/min flow rate droplet density was maximum and volume median diameter (VMD) of droplets was minimum for both brushes. The spinning brush applicator using nylon brush converted higher percentage of liquid into fine droplets than the vegetable fibre brush. The VMD of droplets delivered by nylon brush applicator was 183.4 μm; the VMD and number median diameter (NMD) ratio was 1.23; and the average droplet density was 33.33 droplets/cm^2. The performance of the nylon brush applicator was better than the commonly used hand-compressed sprayer in terms of percentage fine droplets, operator's exposure to pesticide and cost of operation.

Introduction

The conventional hydraulic sprayers require a large volume of water for spraying, thus increases the drudgery and labour requirement in carrying large volume of water. This problem is more acute in arid and semi-arid regions. Moreover, droplets of hydraulic sprayers are not uniform and run-off problem is associated with conventional high volume sprayers. Ultra low volume (ULV) sprayers have the advantages of requiring much less volume of liquid which eliminates the problem of fatigue, high labour cost and run-off. But the cost of the commercially available ultra low volume sprayer is beyond the reach of the poor farmers. To overcome these problems a simple, low-cost, low volume (LV) spinning brush pesticide applicator was developed in order to meet the requirement of small farmers.

Materials and Methods

The details of the developed spinning brush applicator is shown in **Figs. 1** and **2**. It consists of a circulator brush atomizer of 12.30 cm diameter mounted on one end of a flexible shaft. The flexible shaft passes through a 1.10-m long M.S. pipe of 20 mm diameter. A set of bevel gears having 110 teeth on the driver and 12 teeth on the driven gear was used to rotate the brush. The driver gear was mounted on a crank of 12 mm dia which operates on the principles of four-bar mechanism. Bevel gears are supported by the main frame made of 40 × 6 mm flat bars to which the pipe carrying the flexible shaft is attached. A container is provided on the shoulder of the operator and the chemical flows from the container by gravity through a flow restrictor nozzle and drips on the bristless of the brush. Two metallic deflectors are fixed to the frame of the applicator in order to generate fine droplets when the brush rotates at high speed. A canvas strap of 48-mm width is provided to support the applicator on the operator's shoulder. The length of the strap is made ad-

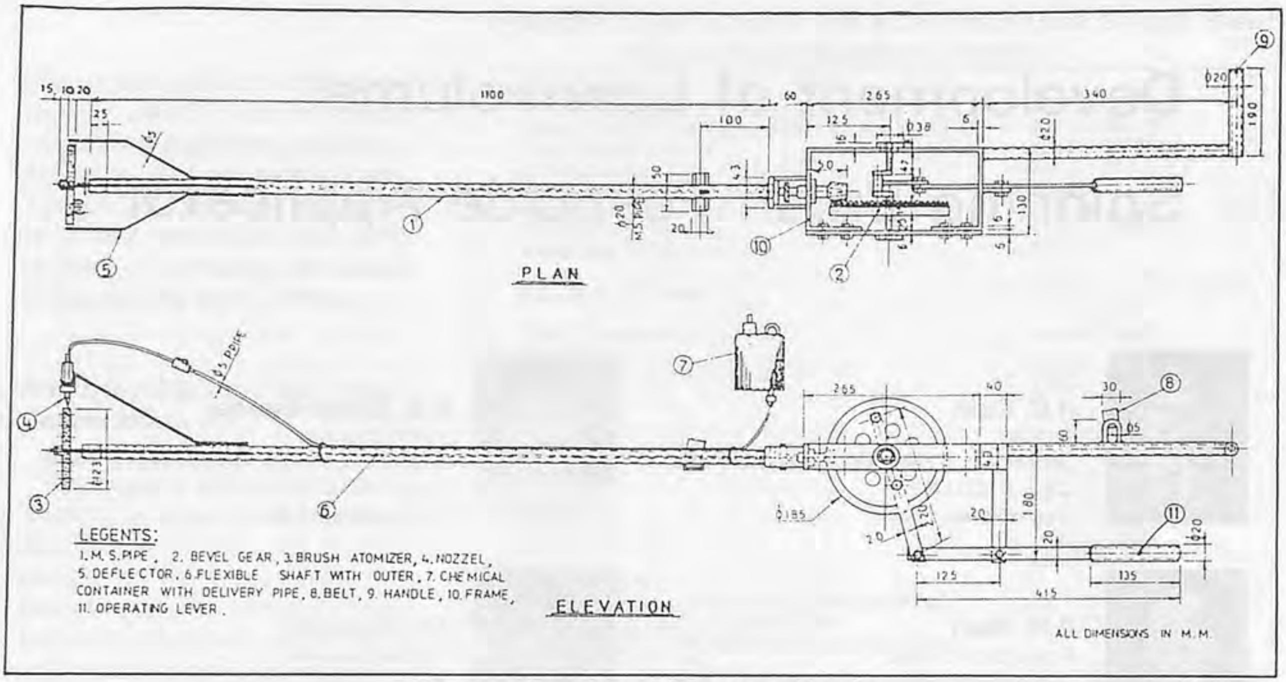

Fig. 1 Low volume spinning brush applicator.

Fig. 2 Spinning brush applicator in operating position.

justable for the operator's comfort and easy operation. The pesticide container (and contents) rests at the back of the operator.

The applicator was tested in the laboratory for vegetable fibre (sisal) and nylon brush at 950 rpm for different flow rate (19,33 and 54 mℓ/min). Droplets were collected on glass slides coated with shoot of burning magnesium ribbon. About 20 cm of magnesium ribbon was used to coat each slide. The diameter of craters formed on the magnesium oxide was measured with the help of microscope using ocular and stage micrometer. True size of the droplets were measured after deducting the spread factor. The droplet density per unit area was determined by counting the number of droplets on glass slide. The volume median diameter (VMD) and number median diameter (NMD) of droplet spectrum were determined in order to know the spray characteristics. The ratio of VMD and NMD was also determined to know the uniformity of spray. The performance of spinning brush applicator was compared with the commonly used hand-compression sprayer.

Results and Discussion

The values of VMD, NMD, VMD-NMD ratio and density of droplet spectrum of the brush applicator are shown in **Table 1**. The spray characteristics produced by the vegetable brush applicator shows that the VMD and NMD of droplets vary from 202.68 to 212.01 μm and 139.13 to 200.54 μm, respectively, for different values of flow rates. VMD of droplets is minimum and droplet density is maximum at 33 mℓ/min flow rate for vegetable fibre brush.

The spray characteristic produced by the nylon brush indicates that VMD and NMD values are minimum and droplet density is maximum at 33 mℓ/min flow rate. The value of VMD NMD ratio for nylon brush and vegetable fibre brush at 33 mℓ/min flow rate were 1.23 and 1.32, respectively, indicating that the spray of nylon brush was more uniform than the spray of vegetable fibre brush. The droplet density of nylon brush was 11.78% higher than the droplet density of vegetable fibre brush at 33 mℓ/min flow rate.

Figure 3 shows the percentage

Table 1. Values of VMD, NMD, VMD and NMD Ratio and Droplet Density of Spray Spectrum

Type of Brush	Flow Rate (mℓ/min)	VMD (μm)	NMD (μm)	VMD / NMD	Average Droplet Density (No/cm^2)
Vegetable Fibre	19	204.52	139.13	1.47	20.50
	33	202.68	152.96	1.32	32.50
	54	212.01	200.54	1.06	27.50
Nylon	19	203.78	163.04	1.25	20.66
	33	183.40	148.91	1.23	36.33
	54	237.82	191.02	1.22	35.50

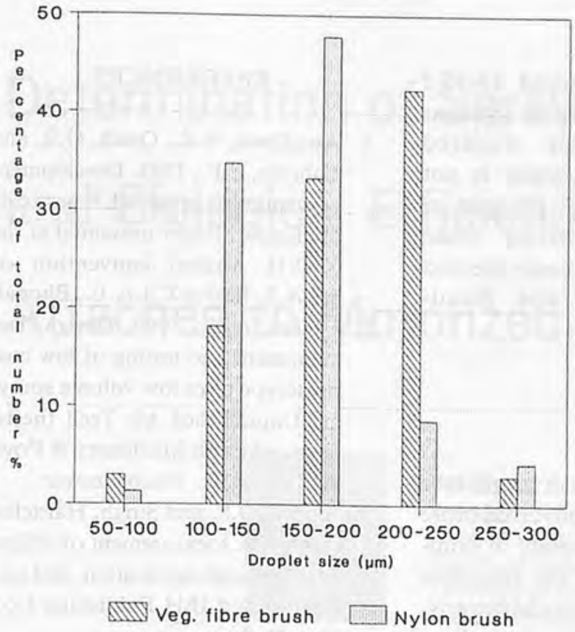

Fig. 3 Distribution of droplets by number.

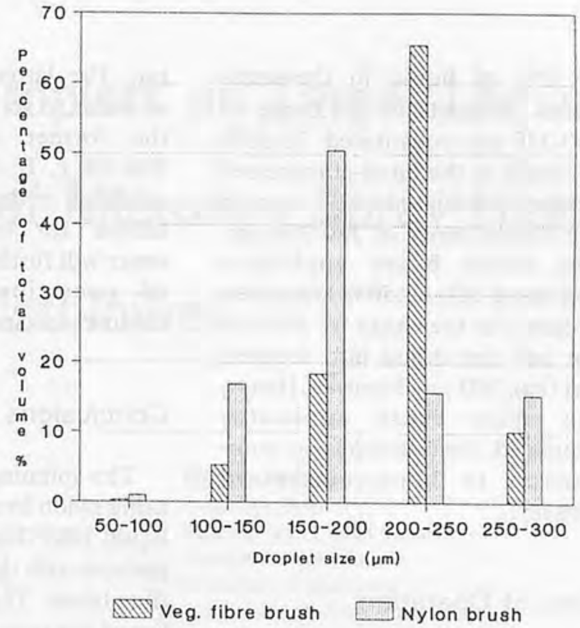

Fig. 4 Distribution of droplets by volume.

of the total number of droplets distribution for vegetable fibre brush and nylon brush applicator. It will be shown that 3% of the droplets of vegetable fibre brush applicator are smaller than 100 μm, whereas 4.34% of the droplets of nylon brush applicator are of that size. In the case of vegetable fibre brush applicator 51.50% of total droplets are within 100-200 μm, whereas 82.60% of droplets lie in the same range for nylon brush. Medium size droplets (200-300 μm) constituted only 13.04% of total number of droplets for the nylon brush applicator compared to 45.45% of droplets of vegetable brush applicator. This shows that more smaller droplets are produced from the nylon brush applicator in comparison with vegetable fibre brush applicator. This may be due to the sticking together of the bristles of the vegetable fibre brush.

The vegetable fibre brush applicator converts only 24.01% of liquid into droplets smaller than 200 μm and the rest, 75.90% of liquid into droplets in the range of 200-300 μm whereas the nylon brush applicator converted 68.50% of liquid into droplets smaller than 200 μm and remaining 31.50% of liquid into droplets in the range of 200-300 μm (**Fig. 4**). Thus, nylon brush converts 184.23% more liquid into fine droplets in comparison with vegetable fibre brush applicator.

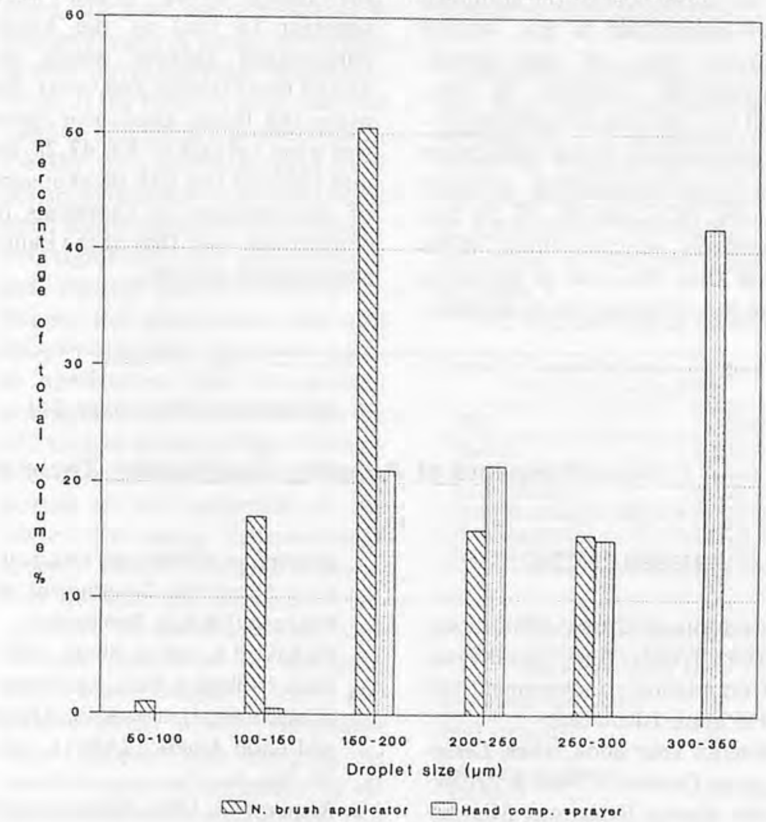

Fig. 5 Distribution of droplets by volume.

Figure 5 shows a comparison of the nylon brush applicator with the commonly used hand-compressed sprayer which converted 21.50% of liquid into droplets smaller than 200 μm. The nylon brush applicator converted

68.50% of liquid in the same range. Droplets in the range of 200-350 μm constituted 78.50% of liquid in the hand-compressed sprayer of which 41.97% were in the droplet range of 300-350 μm. The nylon brush applicator converted only 31.50% liquid into droplets in the range of 200-300 μm and rest liquid into droplets less than 200 μm diameter. Hence, the nylon brush applicator produced finer droplets in comparison to hand-compressed sprayer.

Cost of Operation

The initial cost of the spinning brush applicator is Rs. 700.00 whereas that of the hand-compressed sprayer is Rs. 1 400.00. The cost of spraying using the spinning brush applicator and hand-compressed sprayer were Rs. 19.22 and Rs. 62.50/ha, respectively, which is almost 300% higher than the cost of spraying using the spinning brush applicator. The latter required 10-15 ℓ of water to spray one ha whereas the former sprayer required 200-300 ℓ. If clean water is not available in the field, the cost of labour for transporting clean water will further increase the cost of operation of the hand-compressed sprayer.

Conclusions

The spinning brush applicator using nylon brush converted more liquid into fine droplets in comparison with that of the vegetable fibre brush. The spray characteristics of the spinning brush applicator using nylon brush were superior to that of the hand-compressed sprayer which required more labour and water. By using the brush applicator there was a net savings of Rs. 43.28/ha and reduced the risk of exposure of the operator to chemicals in comparison with that of the hand-compressed sprayer.

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Determination of Spray Droplets on Target Leaves and Biological Efficiency of Micronex Spray Head Attached to Motorized Mistblower

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Abstract

The amount of deposit on the leaves of plant, losses in pesticide and biological efficiency were determined with different injector types and spinning disc revolutions of the micronex spray head attached to motorized mistblower.

The amount of the deposit on the leaves of plant was determined by using the fluorometric method. The biological efficiency achieved with micronex spray head was determined by using real pesticide (agremic) and controlling the red spider (*Tetranychus cinnabarinus* Boisd (Acarina: *Tetranychidae*) on bean plant.

The results of the study indicated that the highest deposit and relative deposition on the plant leaves were achieved by the highest flow rate of the injector and spinning disc revolutions. The highest biological efficiency was 82.97% that was obtained with blue injector and at a disc revolution of 19 000 min^{-1}.

Introduction

The use of pesticide in agricultural production in Turkey still calls for a need. On the other hand, the over use of pesticide is not only waste of pesticide but also causes environmental pollution. Most of the modern pesticides are used in agriculture production in Turkey. But the equipment used for spraying are locally made and need technological improvement. The significant cost reductions in pest control are obtained by reducing the application rate and droplet diameter. However, actual application rate for ground equipment is about 300 L per ha (Zeren and Moser, 1988). Enough active ingredient cannot be transported to the underside of the leaves by using conventional sprayer. Despite the high application dosages the biological efficiency of the chemical is not high enough because of the spraying with coarse droplet (Zeren and Bayat, 1986). Many researchers have suggested that carrying the small droplet on the target by air gives satisfactory results. This can be achieved by using micronex spray head.

In the study, the amount of droplets on the leaves of plant, losses in pesticide and biological efficiency were determined by using micronex spray head attached to a motorized mistblower.

Material and Methods

Droplet deposit and the biological tests were conducted at the laboratory for spraying established in Çukurova University, Agricultural Faculty, Department of Agricultural Machinery. Some properties of used plant are given in **Table 1**.

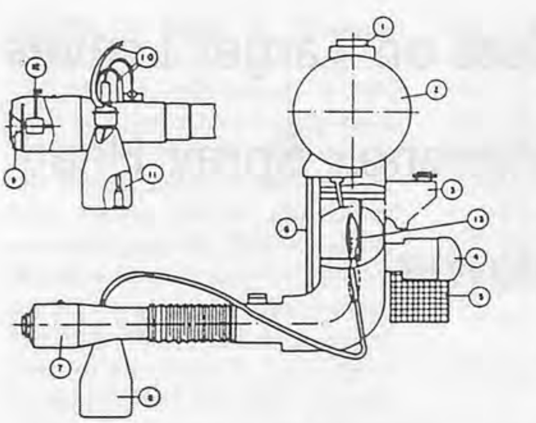
The Micronex spray head which

Table 1. Some Properties of Bean Plant Used in the Study

Item	Property
Variety	Dermason
Starting of trial period	July 1993
Row spacing	120 mm
Plant spacing on the row	150 mm
Plant height	450 mm
Leaf area index	1.25

Table 2. Technical Specifications of Motorized Mistblower and Micronex Spray Head

Motorized Mistblower	
Tank capacity	12ℓ
Motor power	3.73 kW
Spinning vantilator atomiser	6 000 min^{-1}
Gasoline tank capacity	2ℓ
Air velocity	
Micronex spray head	42 m/sec
Non-micronex spray head	32 m/sec
Micronex Spray Head	
Weight	550 g
Bottle capacity	0.5ℓ
Application volume	1-10ℓ/ha
Injector types	Diameter (mm)
Blue injector	0.60
Yellow injector	0,72
Orange injector	1.10
Red injector	1.35



Legend:
1. Tank lid
2. Spray tank
3. Gasoline tank
4. Motor
5. Wheater filter
6. Chassis
7. Micronex spraying head
8. Micronex spray tank
9. Rotary disc
10. Liquid connections pipes
11. Enjector
12. Oil stopper
13. Vantilator

Fig. 1 Function diagram of micronex spray head and motorized mistblower.

was attached to a motorized mist blower was used as equipment. This spray head provides ULV (Ultra Low Volume) application facilities (from catalogue of micronex). The function diagram of micronex spray head and a motorized mist blower are shown in **Fig. 1**.

The technical specifications of motorized mist blower and micronex spray head are given in **Table 2**.

The rotation of disc and carrying of water on the disc are provided by the atomizer air current. It was used in different injector types (bue, yellow, orange and red) and spinning disc revolutions of (11 000, 15 000 and 19 000).

Spray Deposit Studies

The quantity of pestiside deposit on the leaves of the bean plant was determined. In order to collect the tracer deposit on both sides of the leaves, 6 flowerpots were chosen on 2 rows on the table which has 1 m diameter. Applications were treated in different injector types and spinning disc revolutions and each application was repeated three times. At the beginning instead of real pesticide the active ingredient 280 g/ha (2.8 $\mu g/cm^2$) BSF (Brillantsulphoflavin) solution was used. The amount of BSF was equally applied to equal the target in the unit area in different injector types and spinning disc revolutions. Each plant was divided into three zones (I, II and III) and from each plant, 9 leaves were marked before spraying the tracer substance, and filter papers were fixed on both sides of the leaves and which are shown is given in **Fig. 2**.

After spraying the filter papers were collected separately and were put in jars with 50 mℓ of distilled water. The jars were shaken for 15 min. Solution samples were taken from each jar and analyzed quantitatively using a fluorometer. The sprayer deposit of droplets were detected by the Turner Fluorometer (Model 111). Filters used in the fluorometer were 405 (first) and 2A-12 (second). The calibration diagram of the fluorometer was prepared by working with standard BSF solutions at different sensivity levels of fluorometer.

The amount of the deposit on the filter papers and leaves were calculated by using the following equation (Bayat, 1987):

$$fK = m.VL.1/A \quad ...(1)$$

where,

fK: Fluorometric coefficient at the sensitivity level ($\mu g/cm^2$)

m: Concentration factor at the sensitivity ($\mu g/m\ell$)

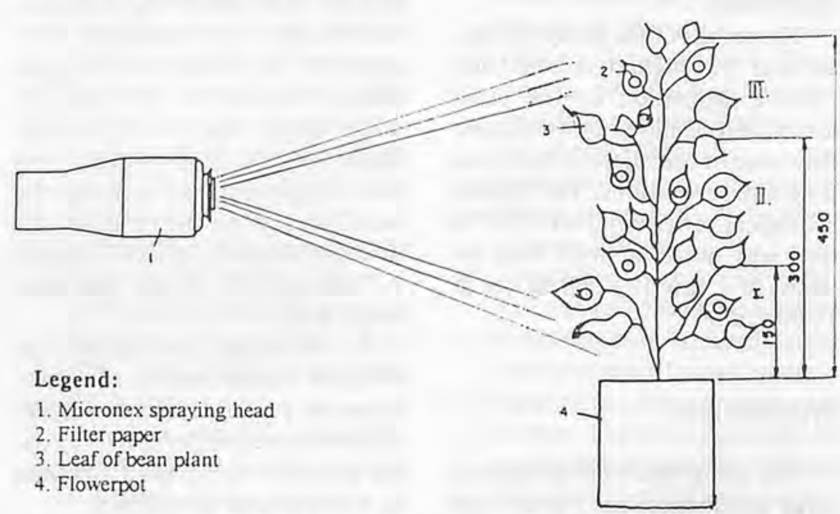
VL: Quality of destilled water for washing out the spray deposit (50 mℓ for 3 filters)

A: Area of filter papers with 40 mm diameter (cm^2)

In the study, 30X sensitivity level of fluorometer was used, fK coefficient at 30X was calculated as $9.90.10^{-5}$ $\mu g/cm^2$. For calculating the spray deposition, fK was multiplied with fluorometric reading of spray solution.

The relative deposit of droplets (RD) of the sprayed solution on the experiment plots, as the percentage of actual quantity used BSF ($2.8\ \mu g/cm^2/1.25 = 2.2\ \mu g/cm^2$) are as follow:

$$RD = \text{Deposit on leaf } (\mu g/cm^2)/2.2 \times 100 \quad ...(2)$$



Legend:
1. Micronex spraying head
2. Filter paper
3. Leaf of bean plant
4. Flowerpot

Fig. 2 Placing of filter papers on the plant.

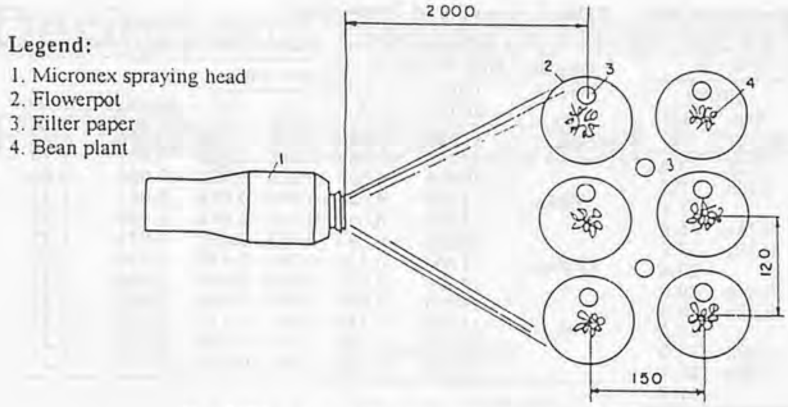


Fig. 3 Diagram used to determine losses in pesticide.

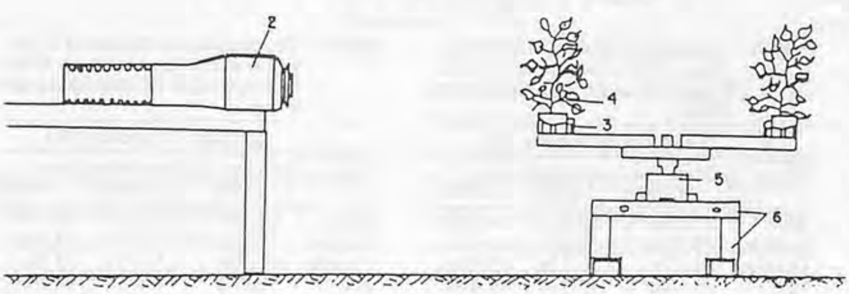


Fig. 4 Mechanism used to determine biological efficiency of spray head.

Table 3. Spraying Periods with Different Injector Types and Spinning Disc Revolution

Injector types	Spraying period(s)		
	Spinning disc revolution (min^{-1})		
	11 000	15 000	19 000
Blue	109.6	77.2	60.6
Yellow	59.0	35.6	30.0
Orange	37.0	22.1	18.2
Red	19.0	13.2	10.0

In different injector and spinning disc revolution, losses in pesticide were determined by placing the filter paper on the soil. Placing of filter paper is shown in **Fig. 3**.

Biological Efficiency Studies

The biological efficiency achieved with micronex spray head was determined by using real pesticide (agremic) and controlling red spider on bean plants. The quantity of pesticides was applied equally to the plant in the unit area with different injector types and spinning disc revolutions which was used in **Table 3**.

The biological efficiency was determined by using a mechanism which is shown in **Fig. 4**.

The distance micronex spray head between target was determined to be 2 m at least. Before and after spraying biological efficiency was determined by counting red spider (adult larva and egg) under the leaves of the bean plant. The biological efficiency was determined by using Henterson Tilton Equation (Karman, 1971).

$$T = (1 - Ts.Ce/Te.Cs).100$$

where,

T = Biological efficiency (%)
Ts = The number of insect after spraying (one day after)
Te = The number of insect before spraying
Cs = The number of insect on the control plants after the treatments
Ce = The number of insect on the control plants before the treatments

Results and Discussion

Spray Deposit

The highest average deposit was determined at the red injector. This value was 0.696 $\mu g/cm^2$ at the 19 000 min^{-1}. The lowest average deposit occured at the blue injector. This value was 0.118 $\mu g/cm^2$ at the 11 000 min^{-1}. When the spinning disc revolution and injector diameter were increased, the average amount of deposit increased **(Table 4)**. This difference became important statistically. In the same way, the highest total relative deposit was recorded at the red injector. This figure was 51.91% at the 19 000 min^{-1}. The lowest total relative deposit was determined at the yellow injector. This figure was 12.55% at the 11 000 min^{-1} **(Table 4)**.

The average deposit on the plant and relative spray are shown in **Table 4**.

For micronex spray head, losses in pesticide are shown in **Table 5**.

As the spinning disc revolution was increased and the injector diameter was reduced and the average of spray losses decreased **(Table 5)**. The highest losses were recorded at the red injector. This value was 0.119 $\mu g/cm^2$ at the 11 000 min^{-1}. The lowest average of losses in pesticide was recorded at the blue injector. This value was 0.026 $\mu g/cm^2$ at the 19 000 min^{-1}.

The biological efficiency was determined for the adult, larva and eggs on red spider on bean plant by using micronex spray head attached to a motorized mist blower and are given in **Tables 6, 7** and **8**.

The highest biological efficiency was 82.97% that was obtained

Table 4. In Different Injector and Spinning Disc Revolution with Micronex Spray Head, Average Deposit on Plant

Item		Spinning Disc Revolution (min^{-1})					
		11 000		15 000		19 000	
		Avg (μg/cm²)	RD (%)	Avg (μg/cm²)	RD (%)	Avg (μg/cm²)	RD (%)
Blue	Upper	0.21b*	9.7	0.45a	20.2	0.52a	23.4
	Lower	0.11c	5.2	0.23b	10.3	0.40a	17.7
	Total		14.93		30.5		41.1
Yellow	Upper	0.16b	7.1	0.37a	16.6	0.35a	15.8
	Lower	0.12b	5.3	0.26a	11.6	0.30a	13.5
	Total		12.5		28.3		29.4
Orange	Upper	0.38b	17.1	0.50ab	22.4	0.65a	29.0
	Lower	0.19ab	8.5	0.24ab	10.7	0.32a	14.5
	Total		25.6		33.1		43.5
Red	Upper	0.37b	16.9	0.61a	27.0	0.69a	31.0
	Lower	0.14c	6.5	0.31b	14.0	0.46a	20.8
	Total		23.4		41.0		51.9

*: Averages shown in the same column are not different according to LSD at 5%.

Table 5. Quantity of Spray Losses

Injector types	Spinning Disc Revolution (min^{-1})	Quantity of Spray Losses				
		Replications				
		I	II	III	Average	Percent
Blue	11 000	0.040	0.035	0.020	0.033	1.17
	15 000	0.034	0.033	0.020	0.029	1.10
	19 000	0.027	0.028	0.021	0.026	0.09
Yellow	11 000	0.041	0.046	0.043	0.043	1.53
	15 000	0.035	0.042	0.043	0.040	1.42
	19 000	0.033	0.033	0.037	0.035	1.25
Orange	11 000	0.120	0.098	0.110	0.110	3.92
	15 000	0.054	0.090	0.056	0.066	2.35
	19 000	0.045	0.061	0.056	0.063	2.25
Red	11 000	0.135	0.106	0.117	0.119	4.25
	15 000	0.106	0.119	0.076	0.100	3.57
	19 000	0.090	0.084	0.062	0.070	0.25

Table 6. Determining of Biological Effectiveness of Micronex Spray Head in Stage Egg of Red Spider on Plant

Injector Type	Average Efficiency (%)		
	Spinning disk revolution (mm^{-1})		
	11 000	15 000	19 000
Blue	1.26a*	−0.16a	21.31a
Yellow	9.83a	8.67a	22.12a
Orange	4.84a	9.16a	13.79ab
Red	−0.95a	6.20a	−3.61ab

*: Averages shown in column are not different according to LSD at 5%.

Table 7. Determining Biological Effectiveness of Micronex Spray Head in Stage Larva of Red Spider on Plant

Injector Type	Average Efficiency (%)		
	Spinning disk revolution (mm^{-1})		
	11 000	15 000	19 000
Blue	52.02a*	54.87a	64.04a
Yellow	59.23a	59.93a	63.69a
Orange	40.10a	50.17a	57.00a
Red	51.60a	53.70a	59.40a

*: Averages shown in column are not different according to LSD at 5%.

Table 8. Determining of Biological Effectiveness of Micronex Spray Head in Stage Adult of Red Spider on Plant

Injector Type	Average Efficiency (%)		
	Spinning disk revolution (mm^{-1})		
	11 000	15 000	19 000
Blue	64.78a*	82.18a	82.97a
Yellow	67.73a	72.14a	74.15a
Orange	67.75a	74.15a	75.02a
Red	70.80a	75.39a	80.00a

*: Averages shown in column are not different according to LSD at 5%.

from using the blue injector and at the disc revolution of 19 000 min^{-1} on the controlling adults of the red spider (**Table 8**). The lowest biological efficiency was −3.61% that was determined from using the red injector and at the disc revolution of 19 000 min^{-1} on the controlling in stage egg of the red spider (**Table 6**).

Conclusions

1. The highest deposits were determined at the red injector and 19 000 min^{-1} although the lowest deposit occured at the blue injector with 11 000 min^{-1}.

2. The highest loss in pesticides was recorded at the red injector with 11 000 min^{-1}. However, the lowest loss in pesticides was determined at the blue injector with 19 000 min^{-1}.

3. The highest biological efficiency was 82.97% that was obtained from using the blue injector and at a disc revolution of 19 000 min^{-1} on the control of the red spider.

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Design and Development of Equipment for Pelleting Decomposed Coir Pith

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Abstract

A unit for pelleting decomposed coir pith was designed, fabricated and tested for its performance. The effect of moisture content and particle size on capacity, compaction ratio, expansion ratio and durability index were studied. The pellets produced at 25% moisture content with particle size of 8 mm had optimum durability of 0.82 with good compaction and expansion ratios of 3.14 and 1.33, respectively. The capacity of the unit was 101.7 kg/h.

Introduction

The coir pith, a waste from coconut husk after separating the coir fibre amounts to about 3.4 lakh tonnes from the industry in India[6]. This waste material is being thrown on the highways and burnt for want of space for disposal. The coir pith is nowadays decomposed by means of urea and *plerotus Sp.* and used as fertilizer. The practice of using fertilizer pellets is becoming popular in recent years to provide nutrients to plants throughout the cropping period. Hanck and Koshino[2] point out that the fertilizer pellets are less susceptible to loss of nutrients by leaching, by immobilization or fixation or by volatilization. Keeping the advantages of pellets in view, a research project was undertaken to develop an equipment for pelleting of decomposed coir pith.

Materials and Methods

Decomposing Coir Pith

The coir pith collected from the coir industries was sieved and mixed with urea and *plerotus sp.* and the moisture content was adjusted to 25%. The mixture was kept at room temperature for 26 days as per the procedure laid down by Nagarajan et al.[5] in order to convert the coir pith into compost.

Development of Pelletizer

The pelletizer mainly consists of a screw press, barrel, feed hopper, cutting knife, motor, gear box, die and oscillating tray. The capacity of the unit was fixed at 100 kg/h. A reduction gear box of 10:1 ratio was selected and coupled with 5 hp electric motor. The density of the decomposed coir pith was determined at 57.7 kg/m^3 as per Mohsenin[4].

The other parameters of the equipment were determined using the formulae of Henderson and Perry[3]:

$$Q_t = [\pi/4(D^2 - d^2).P.N \times 60]\,\varrho$$

Where
Q_t = Theoretical capacity of the unit kg/h.
D = Diameter of the barrel
d = Diameter of the screw
ϱ = Density of decomposed coir pith
P = Pitch of the screw
N = rpm

Since decomposed coir pith is mild abrasive and less free flow material a loading factor is introduced.

$$Q_A = Q_t \times K$$

Where
Q_A = Actual capacity
Q_t = Theoretical capacity
K = Loading factor (0.25 for decomposed coir pith)

Based on the design calculations, a pelleting unit was fabricated and tested for its performance (**Fig. 1**). The decomposed coir pith fed into the pelletizer was compressed by a screw auger and came as solid cylinder through the die. The knife provided at the end cut the pellets to a size of 10 mm. The wet pellets fell over the corrugated oscillating platform and the edges were rounded off. Then the pellets are dried in the shade for

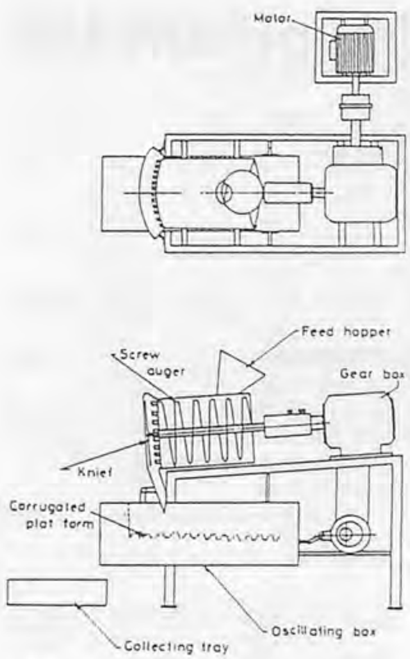

Fig. 1 Pelletizer for decomposed coir pith.

Table 2. Effect of Particle Size and Moisture Content on Compaction Ratio, Durability Index and Expansion Ratio of Decomposed Coir Pith Pellets

Moisture Content (%)	Partizle Size (mm)											
	Compaction Ratio				Durability Index				Expansion Ratio			
	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4	0.8	1.0	1.2	1.4
20	3.01	2.92	2.83	2.73	0.73	0.71	0.68	0.60	1.35	1.38	1.40	1.42
25	3.14	3.03	2.95	2.89	0.82	0.78	0.72	0.66	1.33	1.35	1.37	1.40
30	3.26	3.17	3.12	3.02	0.92	0.88	0.84	0.78	1.28	1.31	1.35	1.37
35	3.35	3.27	3.25	3.11	0.98	0.96	0.90	0.86	1.25	1.28	1.31	1.34

Table 1. Effect of Moisture Content on Capacity of Pelletizer

Moisture Content	Actual Capacity (kg/h)
20	103.2
25	101.7
30	98.9
35	96.4
40	96.2

72 h. The particle sizes of 0.8 mm, 1.0 mm, 1.2 mm and 1.4 mm were selected for the study. The trials were conducted at moisture levels of 20, 25, 30, 35 and 40% and the capacity, compaction ratio and durability index were determined. The desired moisture content was obtained as per Bisht[1]. The compaction ratio and durability index were calculated according to Young et al[7].

Results and Discussion

Performance of the Pelletizer

The developed pelletizer was tested for its performance. The actual capacity of the unit ranged between 95.5 kg and 103.2 kg. for the materials tested. It did not change with the particle size but decreased its moisture content (**Table 1**). The variation might be due to increased moisture content of the material which obstructs the flow of the coir pith inside the barrel and the screw assembly.

It was noticed during the trials conducted at moisture content levels of 35% and 40% that a film of water was adhering to the surface of the pellets. This may be due to the compressive force which is responsible for pelleting the compost by squeezing the product and releasing the excess moisture to the outer surface of the pellets.

Table 2 shows the effect of moisture content and particle size over compaction ratio, durability index, and expansion ratio. It is evident from the table that the compaction ratio increases linearly with the moisture content. In all cases the compaction ratio was maximum at 40% m.c. But the pellets collected in the oscillating tray not only hampered the process of globulation but also caused the sticking of the pellets with each other and ultimately became a solid mass. The pellets obtained at 30% m.c. was more or less round in shape and there was no disintegration or sticking. The 20 and 25% m.c. trials showed slight disintegraton of pellets in the oscillating platform. The less compaction might have influenced this phenomenon. In the 35% m.c. trials about 10% of the pellets stuck with each other. At high m.c. trials the heat generated during the pelletization might have contributed to the higher compaction. It is clear from the table that the compaction ratio decreases with the particle size. The pore space in the bigger particle is greater and probably this resulted to the less compaction of the pellets. In the smaller size particles the surface area (per unit volume) is greater and hence have more binding action and so more compaction.

The durability of the of the pellets decreased as the particle size increased. Since the stress relaxation is greater in the particle size of 1.2 and 1.4 mm compared to that of 0.8 and 1.00 mm which might have contributed to less durability. It is also clear from the table that as the moisture content increases the durability also increases for all particle sizes.

At the moisture content of 20 and 25%, the durability index was only 0.73 and 0.82 (for 0.8 mm particle size). As the moisture content increased by 5% the durability index soared to 13%. This indicates that the moisture plays a vital role in imbibing the materials together at high pressures during the pellet formation.

Expansion Ratio

The expansion of the pellets was observed immediately after the pelletization. The expansion ratio increased with the particle size and decreased with the moisture content. The same trend was noticed in all the trials.

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(Continued on page 38)

Evaluation of Various Paddy Harvesting Methods in Orissa, India

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Abstract

Timely harvesting of paddy is very important in minimizing field losses. Since this operation is labour consuming and expensive, steps have been taken to evaluate and select an appropriate harvesting method for Orissa. It has been observed that the sickle manufactured by Gujarat Agro Industries Corporation (G.A.I.C.) was superior to locally available sickles. By means of this improved sickle the local varieties of lodging paddy can be cut efficiently. But for high yield and local paddy varieties that are or do lodge erect at the time of harvest, power tiller-operated vertical conveyor reapers are preferred over tractor-operated vertical conveyor reapers. The average harvesting costs per ha are Rs. 520.00, Rs. 251.67 and Rs. 351.80 for G.A.I.C sickle, power tiller-operated vertical conveyor reaper and tractor-operated vertical conveyor reaper, respectively.

Acknowledgement: The authors are grateful to the Indian Council of Agricultural Research (ICAR) for providing financial assistance to undertake this research work.

Introduction

Orissa State is located in the east coast of India. Its total land area is 15.54 million ha. The total cultivated area in 1990-91 was 6.423 million ha which was 41.3% of the total area. The total Kharif paddy area is 4.189 million ha which is 65% of the total cultivated land in addition to 0.215 million ha for summer paddy. Paddy is the main crop. Its failure or success greatly affects the agricultural economy of the state. Timely harvesting of this crop has manifold advantages, particularly in minimizing the field losses. In Orissa harvesting of paddy is carried out by means of traditional hand sickle which is cumbersome as well as labour intensive. In order to switch over from this traditional method of harvesting paddy, studies were conducted in order to compare the performance and economics of other harvesting methods using 1) tractor-operated vertical conveyor reaper; 2) power tiller-operated vertical conveyor reaper; and 3) G.A.I.C. hand sickle.

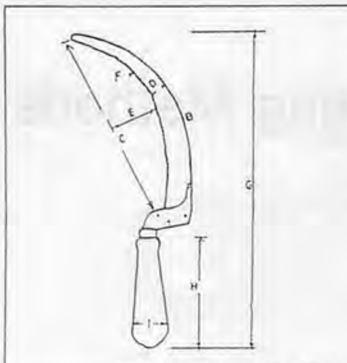
Materials and Methods

The details of G.A.I.C. sickle, power tiller- and tractor-operated vertical conveyor reapers are shown in **Figs. 1**, **2** and **3**, respectively. The field operation of power tiller- and tractor-operated vertical conveyor reapers are shown in **Figs. 5** and **6**, respectively.

The experiment utilized a complete randomized design with three treatments and five replications as follows:

T_1 = Harvesting by tractor-operated vertical conveyor reaper;
T_2 = Harvesting by power tiller-operated vertical conveyor reaper; and
T_3 = Harvesting by using the G.A.I.C. sickle

The plot sizes chosen for each



PHYSICAL DIMENSIONS OF G.A.I.C SICKLE BLADE

TOTAL WEIGHT	LENGTH (cm)				PITCH OF TEETH	DEPTH OF TEETH	ANGLE OF TEETH
	TOTAL SICKLE LENGTH	CUTTING SURFACE OF BLADE	OUTER CURVE OF BLADE	CHORD LENGTH OF BLADE			
217	35.0	23.3	30.2	23.4	0.22	0.16	60

MAXIMUM BLADE WIDTH (cm)	MAXIMUM THICKNESS (cm)	RADIUS OF CURVATURE (cm)	CONCAVITY OF BLADE (cm)
2.5	0.17	20	3.6

PHYSICAL DIMENSIONS OF G.A.I.C SICKLE BLADE & HANDLE

CS - CL RATION	CENTRE OF MASS (% OF TOTAL LENGTH FROM PROXIMAL END)	PERPEDICULAR DISTANCE OF CENTER OF MASS FROM LINE & AXIS	LENGTH OF HANDLE (cm)	DIAMETER OF HANDLE (cm)
1.05	40	2.4	12.5	3.4

Fig. 1 Characteristics of the G.A.I.C sickle.

treatments was 1 000 sq.m. or 40 m × 25 m. For treatment T_1, the headland was cut 3 mt. from four sides of each plot whereas for T_2 the headland was cut 1 m from four sides of each plot by means of GAIC hand sickle for the movement of the reapers and to avoid clogging. The field observations were taken for the effective field capacity, manual headland cutting and other losses. The losses were calculated using the following formula:

$$Wg(t) = Wg1 + Wg2 + Wg3$$

Where,
Wgt = Header losses
Wg1 = Weight of loose grain on ground
Wg2 = Weight of grains from cut panicles fallen on ground
Wg3 = Wt. of grains from uncut panicles after harvest

$$H = \frac{Wgt - Wgo}{Yg}$$

Where,
H = Percentage of header loss
Wgo = Preharvest loss
Yg = Yield (gm/m^2)

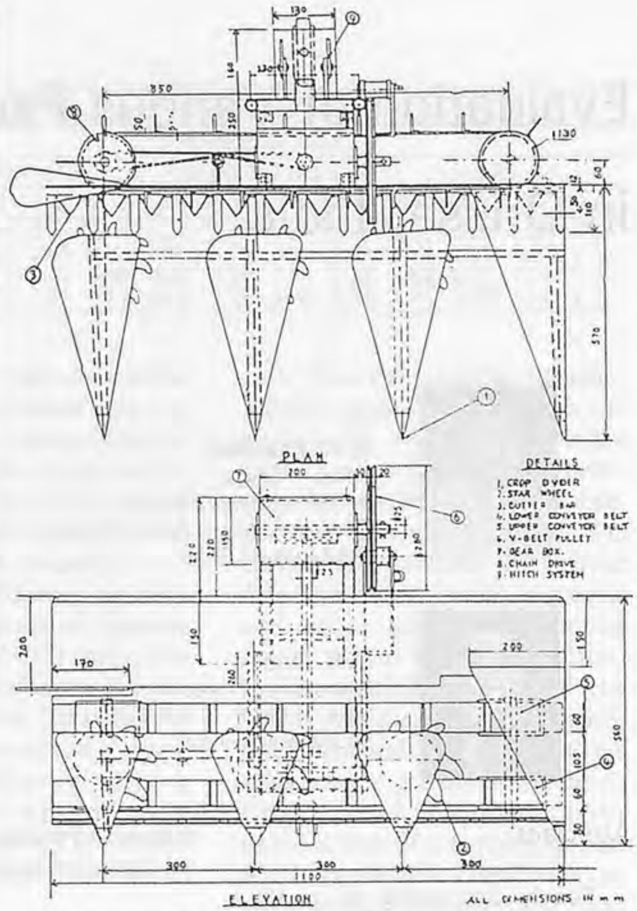


Fig. 2 Sketch of power tiller-operated vertical conveyor reaper.

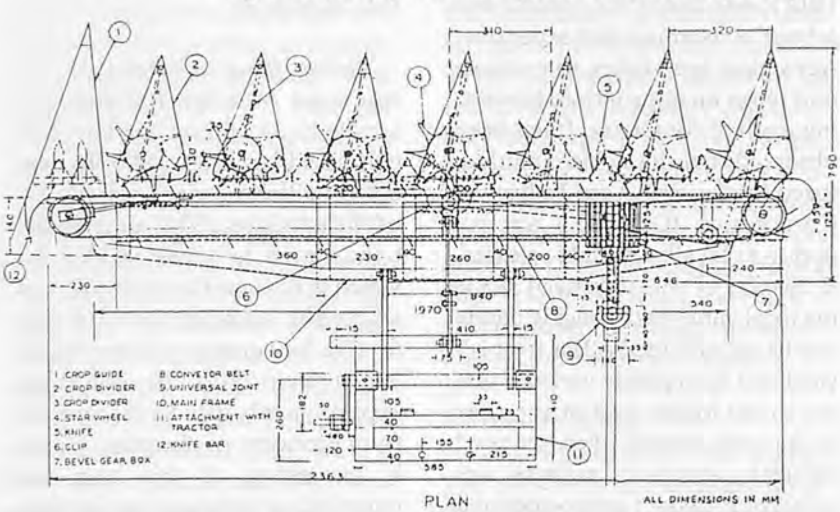


Fig. 3 Front mounted tractor-operated reaper.

Results and Discussion

The experiment was conducted at the Central Rice Research Institute. The paddy variety 1 018 with a maturity of 160 days was chosen for the study. Harvesting was done from the 161st day to 165th day after germination. The average plant density was 250-275/m^2. The row-to-row and plant to plant spacing were 20 cm and 10 cm, respectively. The average inclined angle of the plants was 9°. The number of tillers per hill ranged from 6 to 11. There

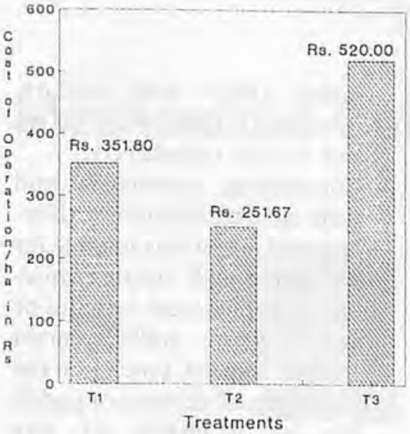


Fig. 4 Comparison of cost of operation in various treatments.


Fig. 5 Power tiller-operated vertical conveyor reaper in operation.


Fig. 6 Tractor-operated vertical conveyor reaper in operation.

Table 1. Effective Field Capacity of Various Treatments (Unit: ha/h)

Replications	Treatments			
	T_1	T_2	T_3	Block Total
R_1	0.535	0.185	0.006	0.726
R_2	0.530	0.174	0.006	0.710
R_3	0.524	0.178	0.006	0.708
R_4	0.546	0.183	0.006	0.735
R_5	0.529	1.175	0.0059	0.7099
Total	2.664	0.895	0.6299	3.5889

G = 3.5889, C.F. = 0.8586.

Table 1a. Summary of Parameters

Source of Variation	Degree of Freedom	Sum of Squares	Mean Sum of Squares	F-ratio	F-ratio from Table
Between Treatments	2	0.7211	0.360550	14422	F(2,12) = 3.89
Error	12	0.0003	0.000025	—	—
Total	14	0.7214	—	—	—

Table 2. Header Losses of Tractor-operated Vertical Conveyor Reaper at Different Operating Speeds

Av. Speed (km/h)	Wgo (gm)	Wg1 (gm)	Wg2 (gm)	Wg3 (gm)	Wgt (gm)	Yg (kg/sq.mt)	H%
3.2	7.2	56.1	0.0	60.2	116.3	3.5	3.1
3.4	3.1	51.1	70.5	0.0	121.7	3.8	3.0
3.6	12.8	40.2	88.3	0.0	128.6	3.7	3.1
3.8	9.8	26.7	89.4	0.0	116.1	3.5	3.0
4.0	6.5	25.0	82.5	79.2	186.7	3.3	5.3
Av. 3.6	7.8	39.8	66.1	27.8	133.9	3.5	3.5

Table 3. Header Losses of Power Tiller-operated Vertical Conveyor Reaper at Different Operating Speeds

Av. Speed (km/h)	Wgo (gm)	Wg1 (gm)	Wg2 (gm)	Wg3 (gm)	Wgt (gm)	Yg (kg/sq.mt)	H%
2.4	6.5	18.3	62.3	0.00	80.6	3.6	2.6
2.6	9.1	30.4	55.6	0.00	86.1	3.5	2.2
2.8	4.2	22.3	60.4	0.00	82.7	3.5	2.2
3.0	6.6	20.5	21.3	70.04	111.9	3.9	2.7
3.2	3.9	44.2	00.0	60.45	104.7	3.6	2.8
Av. 2.8	6.0	27.1	39.9	26.10	93.2	3.6	2.5

Table 4. Comparative Cost of Harvesting per Hectare (Unit: Rs/ha)

Treatment	Mannual Harvesting	Unskilled Labour	Machine Harvesting	Total
T_1	184.08	3.79	163.93	351.80
T_2	65.52	15.26	170.89	251.67
T_3	520.00	—	—	520.00

were 40 to 50 hills/m^2. The average moisture content of the grains was 21% and that of the straw was 49%.

The gentle curve of the serrated blade of the G.A.I.C. sickle made cutting of the paddy stalks easy. The stalks were cut 5 cm from the ground enabling. A 3-4% more straw output compared to the use of local sickles. This keeps the field neat for which pests and pathogen cannot take shelter under the residual stubs. The labour requirements for harvesting using the G.A.I.C. sickle and local sickle were 166.4 and 176 man-h/ha, respectively. The G.A.I.C. sickle blade was made up of high carbon steel as a result of which there was no wear and tear of the blade.

From the C.R.D. test the tractor-operated vertical conveyor reaper was the best considering the effective field capacity. The use of the power tiller- and tractor-operated vertical conveyor reapers required a labourer each was to remove the stalks left uncut in the field.

The header losses of the tractor-and power tiller-operated vertical conveyor reapers are shown in **Tables 2** and **3**, respectively.

In the **Table 2**, it will be shown that the header loss of the tractor-operated vertical conveyor reaper was minimum, i.e., 3.03% at optimum working speed of 3.8 km/h. On the other hand, for the power tiller-operated vertical conveyor reaper **(Table 3)** the header loss was minimum at 2.2% at optimum working speed of 2.8 km/h.

The costs of harvesting for each

of the treatments are shown in **Table 4**. The cost of operation for tractor- and power tiller-operated reapers were Rs. 135.00/h and Rs. 35.00/h, respectively. The wage of unskilled labour, per the government's approved rate of Rs. 25.00 per 8 working hours was considered in determining total costs.

It is evident from **Table 4** that the cost of harvesting using the power tiller-operated vertical conveyor reaper is cheaper than for the tractor-operated vertical conveyor reaper. There was a savings of Rs. 268.33/ha for the power tiller-operated vertical conveyor reaper over that of the manual harvesting using the G.A.I.C. sickle. There was also a savings of Rs. 168.20/ha for the tractor-operated vertical conveyor reaper over that of the manual G.A.I.C. sickle. Considering the analysis of effective field capacity and cost of operation, the power tiller-operated vertical conveyor reaper was more suitable over the other treatments. Manual harvesting using the G.A.I.C. sickle was time consuming and expensive. However, tractor-operated reaper was beyond the reach of the common farmer. Moreover the small, scattered land and large bunds are the limiting factors behind the promotion of the tractor-operated vertical conveyor reaper in Orissa. Even as the power tiller-operated vertical conveyor reaper was more suitable over the tractor-operated harvester, the former is effective only for the erect paddy varieties. Hence, the G.A.I.C. sickle was more suitable for harvesting the lodged varieties of rice crop compared with other local sickles used in Orissa.

Summary and Conclusions

The following conclusions are drawn:

1. The harvesting cost/ha using the G.A.I.C. sickle, power tiller-operated reaper and tractor-operated reaper were Rs. 520.00, Rs. 251.67 and Rs. 351.67, respectively.
2. The header losses for the G.A.I.C. sickle, power tiller- and tractor-operated V.C.R. were 0.7, 2.2 and 3.03%, respectively. The losses in power tiller- and tractor-operated reapers were minimum at their optimum operating speeds of 2.8 and 3.8 km/h.
3. The average height of cut for the paddy stalks were 5 cm for G.A.I.C. sickle and for the power tiller- and tractor-operated V.C.R. were 10 cm and 15 cm, respectively.
4. Considering economics and field capacity, the power tiller-operated reaper was suitable for harvesting high yielding varieties and other local varieties of paddy whose stalks remain erect at harvest time. For the lodging local varieties of paddy the performance of the G.A.I.C. sickle was most suitable.

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(Continued from page 34)

Design and Development of Equipment for Pelleting Decomposed Coir Pith

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Mechanized Cultivation of Summer-sown Peanut

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Abstract

According to the requirements of the cultivation pattern, environment and agricultural techniques of summer-sown peanut, this paper analyses the mechanized operating techniques of interplanting and plastic-film-covered sowing of peanut in the fields with stubble. It also discusses the technological design and mechanical equipment which are both practical and economical.

Introduction

Wheat and peanut are the most favored grain crop and oil crop, respectively, for their excellent flavor and nutrition. In order to get bumper harvests for both grain and oil, hence increase the economic benefits, a great deal of research and exploration have been made on the cultivating techniques of growing two crops of wheat and summer-sown peanut annually. Satisfactory results have been obtained. In the meantime, great importance has been attached to the research on mechanized cultivation techniques of summer-sown peanut, in order to free the farmers from much manual labor.

With an annual sown area of about 800 000 ha, Shandong province is the key region for the production of peanut in the country. The area for peanut cultivation represents up about 30% of all the area for economic crop production. Over 1/3 of the peanut sowing area comes from summer-sown peanut. In order to produce more grain and oil from the limited cultivated land, the area for summer-sown peanut cultivation is on the increase.

Traditional Method of Growing Summer Peanut

In Shandong Province, there are two main methods of peanut cultivation, namely; interplanting and summer sowing after the winter wheat is harvested. In the lower altitude areas where the effective accumulated temperature between post-wheat-harvesting and before the latest harvesting time of peanut is enough for the growth of peanut. Post-wheat-harvest sowing (also called direct seeding) is applied. In this case, the techniques are not difficult and the mechanization can be easily applied. In the higher altitude areas, however, interplanting or planting peanut between wheat rows, must be used. It is usually used as a way to fill the gaps between seedlings. Nevertheless, interplanting cannot be done easily, especially when mechanization is not available.

Therefore, it is of great significance to give up the traditional method of interplanting summer peanut between rows of wheat in favor of a new pattern of cultivation which can produce both more wheat and peanut and easy to mechanize.

Modern Method of Growing Peanut in Summer

The plastic-film-covered cultivation of summer sown peanut is beneficial in that it can increase the temperature, protect soil moisture and keep a good physical and chemical condition of the soil. The new technique using plastic-film-covered cultivation of peanut is based on revealing its biological characters. It can bring about a 20% increase of peanut output and a 25% reduction in seeds used and a 40% reduction in fertilizer. The main features of the technology are:

1. No application of fertilizer to the whole layer of topsoil, no fertilizer with the seeds, fertilizer only in the fruiting-zone, and soil of 0-10 cm deep needs only 750-1 500 kg of fertilizer/ha;
2. Single-seed sowing is applied with 225 000-255 000 plants/ha;
3. Without building ridge-bordered plots in advance, peanut seeds are sown on level land; seeds are covered with soil which is then covered with plastic film and a ridge is built above the line of the sowing row. The ridge (loose soil) is 5-6 cm high. Three rows form a plot;
4. Six to eight days after sowing, when the plumular axis grows through the plastic film, the ridge is removed from on the plastic film, leaving the film on the same level with the land; and
5. When most seeds have sprouted, soil is placed along the

row of peanuts, 1 inch high.

Mechanization at this stage is ideal because:

1. Fertilizer application in the fruiting-zone is convenient as the soil and fertilizer can be mixed evenly;

2. A sufficiently even and straight rows of single seeds is maintained; and

3. The right position between the sowing tape and plastic film is maintained, thus the ridge above the film and the sowing row beneath the film is kept in the same position.

The following processes in this pattern resemble handcraft work and are difficult to be mechanized.

1. When removing the ridge from the film, both the seedling and the film are liable to be damaged.

2. During the time when most needles are coming down, it is quite difficult to spread soil evenly on the film under the plants, so is the case of removing, transporting and throwing of the soil.

3. As three rows form a plot, it is particularly difficult to spread soil on the film above the middle row. It is even more difficult if you want to spread the soil into the side furrow of the plot.

However, particular care has to be observed when the ridge is removed from the plstic film (item No. 5 above) as both film and seeds are liable to be damaged. Also, when most seeds have sprouted, spreading soil under the young leaves of the peanut plants must be done with utmost care so as not to damage the fragile plant. This is particularly true for spreading soil on the middle row (item No. 3 above).

Mechanization and Use of Plastic Film Soil Cover

The new technology of using plastic film as soil cover in the cultivation of summer-sown peanut requires some technique in using farm machinery. This procedure promises not only to render obsolete the back-breaking traditional method of cultivation but also ensures economical cultivation and better crop yield, hence better income for the peanut growers.

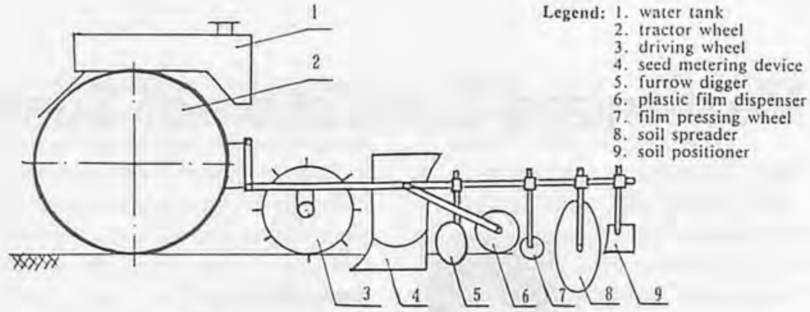

Fig. 1 Schematic diagram of the peanut planter.

Field Preparation Technique

Ploughing and fertilizer application — Soon after the winter wheat harvest, the field should be ploughed before sowing the peanut. The purpose is to bury the wheat stubble, loosen the soil and at the same time apply fertilizer to shallow fruiting zones. There are two prescribed ploughings, namely; turn-over and non-turn over ploughings which depends on the height of the wheat stubble.

a. If the height of the wheat stubble is under 15 cm and the soil is friable, a rotary cultivation or driving gear-hobbing harrow should be used to till the soil once or twice 12-14 cm deep after spreading the fruiting-zone fertilizer. In this way, the fertilizer is mixed with the soil rather evenly.

b. If the height of the wheat stubble is more than 25 cm, and the straw is tattered hence leaves a thick vegetation, turn-over loughing or use of rotary tiller is necessary in order to clear the stubble. After the field is ploughed, the fertilizer and weedicide should be applied and then harrowed once or twice to mix the fertilizer and weedicide with the soil as in item *a* above.

c. The use of plough or rotary tiller and harrow (item *b* above) could loosen the soil which then needs to be pressed somewhat in order to sow the peanut seeds properly.

Combined Operation of Sowing and Plastic Film Laying

This combined operation is preceded by the formation of two-row plots to make it convenient for laying the plastic film later, spreading soil on the film and removing it eventually. So, the seeds are sown, the plastic film is layed and soil is spread on top of the film. Then ridges of 5-6 cm high are formed on top of film directly above the row of sown seeds (**Fig. 1**).

The Peanut Seeds Sprout

When the plumular axis sprouts through the plastic film and ridge after 6-8 days from sowing, the ridges are removed by hand and spread around the growing sprouts. Some plastic films are coated with weedicides and no further application of weedicides are necessary, especially when weedicides were applied during land preparation. When the soil appears to be dry, the plants may be watered until they are able to grow on their own.

The Peanut Combine Planter

The peanut planter is otherwise called a combine considering that it incorporate in its structure the following features: water tank mounted on the tractor; a tractor

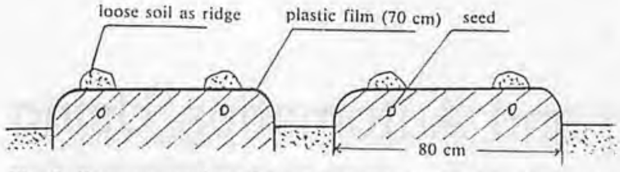

Fig. 2 Cross-cut section of two-row plots showing the ridges atop seeds and plastic film position.

Table 1. Result of Field Performance (Unit: cm)

Parameter	Replication 1	2	3	4	5	Mean
Height of ridge	5.5	4.5	4.0	6.2	5.0	5.0
Width of ridge	48.5	48.0	48.0	47.0	48.2	48.0
Depth of planting	4.2	4.2	6.0	4.9	4.9	4.7
Seed spacing	10.0	9.5	11.0	11.0	11.0	10.4
Row spacing	28.0	28.0	28.0	28.0	28.0	28.0

wheel; driving wheel; seed metering device; furrow digger; plastic film dispenser; plastic film pressing wheel; and a soil positioner **(Fig. 2)**. The combine is operated by 9-11 kW double-axis tractor. The tractor operator controls the functioning of the features cited above.

Specifications of the planter include the following:

1. Application of water from tank: 900-1 800 ℓ/ha
2. Dimensions: 1 880 × 960 × 730 mm
3. Gross weight: 140 kg
4. Operating speed: 2-6 km/h
5. Capacity: 0.16-0.48 ha/h
6. Narrow spacing between rows: 36-40 cm
7. Wide spacing between rows: 48-50 cm

Operating Procedure

There are two alternatives open to the operator in performing the work of the combine: a) Make furrows first, saw the seed singly, lay plastic film, spread soil on film and construct the ridges; and b) First, make furrows, lay plastic film on top of each furrow, punch a hole and drop the seed singly and then spread soil on top of film and construct the ridges.

Alternative *b* is a lot cumbersome as it is technically difficult to punch holes in the film and drop the seed, hence alternative *a* is preferred. For either alternative, it is advisable to use weedicide-coated plastic film.

In spreading the soil on the plastic film, it is necessary to spread the loose soil dense enough to prevent light but thick enough to enable the plumule to prick through the film without pushing it up. A soil-transmitting basket is used in spreading the loose soil on top of the plastic firm for a more reliable and even layer of the soil.

Field Test Result

In order to check the performance of the combine, field tests were conducted in 5 replications. The field (after the winter wheat was harvested) was ploughed, harrowed and tilled by a rotary cultivator considering that the wheat stubble was about 15 to 20 cm high. The fine parameters used in these tests and results were: 1) height of ridge, mean of 5.0 cm or range of 4.0 to 6.2 cm; 2) width of ridge, mean of 48.0 cm or range of 47.0 to 48.5 cm; 3) depth of planting, mean of 4.7 cm or a range of 4.2-6.0 cm; 4) seed spacing, mean of 10.4 cm or a range of 10.0-11.0 cm; and 5) row spacing, mean of 28.0 cm or a constant 28.0 for all replications **(Table 1)**.

The use of the combine planter, after a 2-years' test, showed that labor productivity increased by 30 times and the cost of production was reduced by 50%.

Recommendations

1. Improved quality of mechaization operation of the peanut planter should lead to increase productivity vis-à-vis traditional methods of planting summer peanut.

2. To improve the efficiency of the combine, it is important to leave wheat stubble in the field at an average height of not less than 20 cm and that the wheat straw should not be scattered in the field. This could mean a 20-percent savings on fuel consumption for the use of rotary cultivator or driving gear-hobbing harrow in field preparation.

3. When the moisture content of the upper 10 cm of the soil is less than 10 percent, the rate of water use during planting should be about 2 600 ℓ/ha for a regular growth, hence yield of the crop.

4. As the summer-sown peanut in the Peoples' Repubic of China is usually done on large parcels of land, the use of the combine is a lot more efficient, hence should be promoted.

5. Further experimentation is called for in efficient removal of soil from the plastic film when the crop is emerging already.

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Increase Crop Production and Automation Using Properly Designed Air-pruning Trays/Containers

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Abstract

An integral part of greenhouse production is the use of trays/pots/containers for growing plugs/cuttings/seedlings/plants. A common problem associated with conventional containerized plant production is root-tangling and root-spiraling, resulting in various disadvantages such as deterring root branching and development, slower and non-uniformity in growth in the trays/pots/containers and after the plugs/cuttings/seedlings/plants are transplanted. One reason that causes root spiraling and tangling is the inherent misconception of conventional tray-cell and pot/container designs without considering proper plant-root physiology, resulting in significant losses in profits for growers and farmers. Biotechnology in root-air-pruning utilizes plant system characteristics in conjunction with computer-aided design and system optimization of tray-cell/container configuration to achieve a new effective plant tray/pot/container design and cultural automation that should be of considerable benefit to growers and farmers.

Numerous tests have shown that properly designed air-pruning trays/pots/containers eliminated root-binding for proper and accelerated root formation and facilitated transplanting automation. This, in turn, provided superior and faster plant growth both in trays/pots/containers and after the plants (including plugs, cuttings, and seedlings) are transplanted, resulting in increased yields and quality crops. This further resulted in savings on fertilizer, water, labor, and heating fuel consumption, and greatly increased the utilization cycles of greenhouse facilities by significantly shortening the plant growth periods thus reducing pollution and improving the environment. This article illustrates the systems engineering of improving the interactions between the root formation and container configuration for biotechnically advanced trays using computer-aided design and analysis. It also discusses the important criteria on proper design of trays/pots/containers and illustrates the test results of properly designed air-pruning trays and their effective application in fully automated transplanting.

Introduction

There is an ever increasing demand for improved crop quality, higher yield per unit area of land, reduced growing time, and reduced production costs. It is estimated that farmers as well as other segments of agriculture are faced with the challenge of producing three times as much food by the year 2040. The further challenge is to produce the extra food on no more land than farming uses today and with fewer environmental side effects than farming has today. In the competitive environment of the 1990s, growers and farmers must become more competitive in order to thrive in an era of effective resource utilization and efficiency.

An integral part of greenhouse production is the use of trays/pots/containers for growing plugs/cuttings/seedlings/plants. A common problem associated with conventional containerized plant production is root-tangling and root-spiraling (commonly known as root-binding), resulting in various disadvantages, such as deterring root branching and development, slower and non-uniformity in growth in the trays/pots/containers and after the plugs/cuttings/seedlings/plants are transplanted. One reason that causes root-binding is the inherent misconception of conventional tray-cell and pot/container designs that are small at the bottom and large at the top which is only for easy plant or soil removal without considering proper plant-root physiology, resulting in significant losses in profits for growers and farmers. The basic problems caused by the traditional design misconception remain to be solved. New systems engineering approaches and creative ideas as well as cross-disciplinary efforts to solve these problems are needed.

Systems engineering with life sciences is crucial to economical crop production. Novel bioprocess engineering, both upstream and downstream, is needed for improved crop production systems, including new fundamental engineering knowledge of growth processes for increased agricultural and forestry production. This includes systems capable of culturing normal yet biotechnically altered plants through simple biophysical manipulation of plant root systems. Since the very early stage of plant root formation has profound effects on the future root formation and establishment as well as on the plant growth performance and yields, new understanding of the effective use of root-air-pruning process is urgently needed as it relates to accelerated and superior plant growth. The research on root-air-pruning process has progressed through many years of research and proven results of superior growth and increased plant production (Huang, 1973, Huang and South, 1981, Huang, 1983, Huang and Kato, 1985; Huang and Bowers, Jr., 1986; Huang and Liang, 1987; Huang and Ai, 1992; Huang, 1994; Hu, 1994; Long et al., 1994; Huang and Wang, 1995; Lee et al., 1995). However, computer optimization technique based on the root development data was not incorporated into the air-pruning tray/container design until early 1990 due to difficulties in obtaining such data. Because of the difficulties in observing and measuring the actual mechanism of underground root development for qualitative and quantitative evaluation, there is very little information available on this subject matter even in the field of crop sciences, horticulture sciences, or in forestly. This is also due to the fact that many growers, farmers, researchers and extension agents often taking commercially available trays/pots/containers for granted without thinking how much the properly designed trays/pots/containers would affect their profits or research results. Continued efforts are needed to study the effects of trays/pots/containers on the root development and plant growth before and after transplanting.

Plant Root Growth System Analysis

A plant system consists of shoots and roots. Shoots are the above-ground portion of a plant which interact with the atmospheric environment. Depending on plant species and seasons, the shoot system can contain leaves, buds, flowers, fruits, stems, branches, and a trunk. Roots are the underground portion of plant that interacts with soil environment. The root system anchors the plant to the ground, holding it upright. It contains main root, branches, sub-branches, root hairs and tips, which search for nutrients and water for plant growth. Each root tip has a protective cap that is pushed ahead as it grows. The root system of a plant may have more branches than the shoot system. The shoot-to-root ratio of plant systems, dependent on the species and stage of development, usually remains constant.

Plant root growth systems can be described by discreate growth periods (emergence of new shoots and roots), within which growth is continuous (elongation and expan-

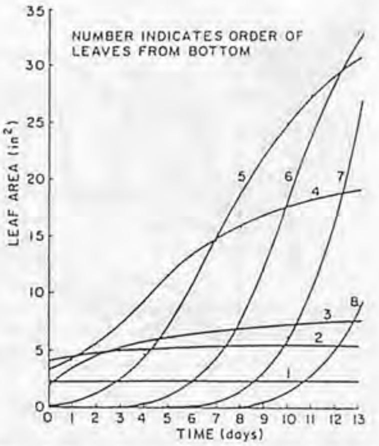

Fig. 1 Growth curves for 8 individual leaves of a tobacco seedling over a 13-day period.

sion of shoots and roots). The continuous growth period starts at a slow pace, growth rate is accelerated following an exponential curve, and then it steadily declines until the shoots and roots reach their late growth stage of slow growth until growth ceases and, therefore, the continuous growth can be described by a S-shaped curve. Then, the discrete growth period starts again. It is interesting to note that the growth of each individual plant leaf or root follows a growth pattern of S-shaped curve, and that the root growth can be suspended at any portion of the growth curve to initiate the discrete growth (Huang, 1994).

Figure 1 illustrates the growth curves of 8 individual leaves over a 13-day period for a tobacco seedling with initial total leaf area of 12 in^2. The curve for the oldest leaf 1 shows the plateau or non-growing upper portion of S-curve. Leaves 2 and 3 show the upper or slow-growth portion of S-curve, and leaf 4 shows the transition portion of S-curve from exponential to slow growth. Leaves 5 and 6 show the entire exponential growth sections of S-curve and leaf 7 and the youngest leaf 8 show the initial portions S-curve starting with slow growth to accelerated exponential growth. The total shoot growth can be obtained by superimposing the individual leaf growth at different development

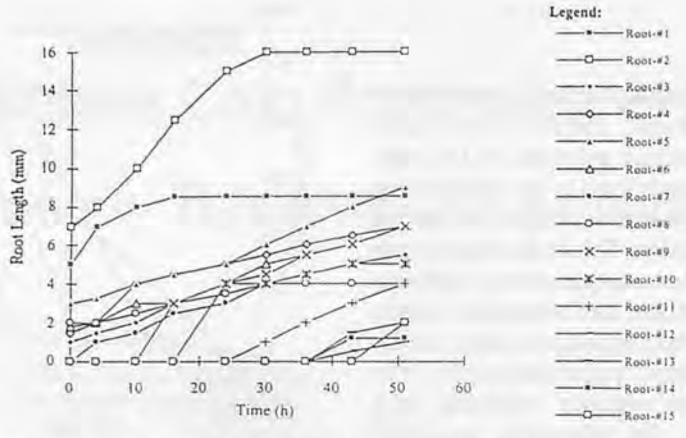

Fig. 2 Growth curves for 15 individual roots of a tomato seedling over a 51-hour period.

levels in different historical periods to form a larger S-shaped curve. This means that the continuous growth period of a plant root growth system follows a pattern of S-shaped growth as exhibited by all biological growth systems, including human and animals (Huang, 1994).

Figure 2 illustrates root length versus time curves over a 51-hour period for a tomato seedling 2 weeks after seeding. Most of the root growth curves **(Fig. 2)** exhibit some portions of S-shaped curve. Root #1 shows upper and plateau portions or slow-growth and non-growth portions of S-curve and Root #2 includes portion of exponential growth. The younger roots show various earlier stages of exponential growth. Under ideal environmental conditions, maximum root growth rate is reached in the early stage of growth following an exponential curve, and from the end of exponential growth, it steadily declines until the root reaches its late growth stage of slow-growth and non-growth. The development of individual root growth described by S-shaped curves are also superimposed at different development levels in different historical periods to form a larger S-shaped curve for total root growth to check with the shoot growth and shoot-to-root ratio.

Conceptual Basis of Root Air-pruning Process

As plant roots emerge through an opening at the bottom of a container supported above ground, the roots shrivel due to contacting dry air and temporarily suspend their growth. This phenomenon is known as air pruning. Proper application of root air-pruning process in conjunction with the use of properly shaped containers significantly increases plant production, improve crop quality and promotes mechanization. Air-pruning alone without the right container will not provide these benefits.

The effectiveness of air-pruning process in promoting root branching can be best shown in **Figs. 3** and **4**. For both air-pruning and conventional trays, the first emerging plant root grows vertically down to the bottom of tray cell following a pattern of S-shaped growth **(Fig. 4-1)**. In a conventional tray cell, the root tends to avoid the drain hole and air-pruning, by shifting the direction if possible, to continue its growth. In an air-pruning tray cell, the open bottom makes it difficult to shift the direction and the root growth is temporarily suspended as soon as the root tip is exposed to the air at the open bottom **(Fig. 4-2)**. Once a root is air-pruned, the discrete growth process immediately causes the plant to start new root branches. Several branchings occur near the media surface first in evenly distributed patterns in a horizontal direction. As root branches grow and encounter a cell wall they turn vertically downward or follow the sidewall toward the bottom of the tray cell, partially seeking better aeration, moisture and nutrients, and partially because the turning angles at the cell wall are more than 90° or the roots encounter least resistance. As soon as the root tips of those branches contact air at the bottom of air-pruning tray their growth is temporarily suspended. In turn, new branching processes occur at those branches **(Fig. 4-3)**. Thus, the branching process continues to fill the tray cell with properly oriented roots in a short period of time, uniformly binding the growing media in the cell/container with fine roots **(Fig. 4-4)**. Proper air-pruning of a root system promotes secondary root growth and eliminates root-binding, resulting in a larger root mass. Air-pruned plugs/seedlings ready for transplanting have cell full of young and vigorous roots that are ready to produce new roots as soon as the plugs/seedlings are transplanted.

Proper application of air-pruning process to root system can suspend the roots' growth at the end of exponential growth portion of the S-shaped growth curve and facilitates new and secondary root branchings. As each branched root is air-pruned, new branches are initiated. As the suspensions of root growth just at the end of exponential growth stage and accelerated branching are repeated, the upper portion of S-shaped growth curves (slow growth stages) are effectively eliminated, resulting in faster root growth and branching, larger root mass, and accelerated superior plant growth. Since the shoot-to-root ratio of

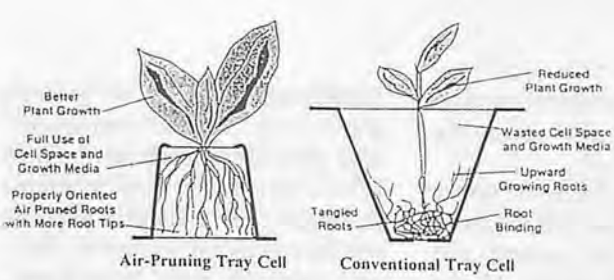

Fig. 3 Comparative plant-root development in air-pruning and conventional tray cells.

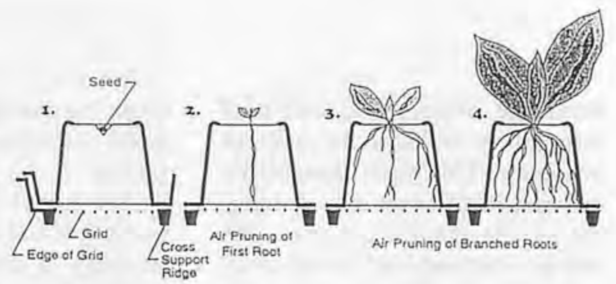

Fig. 4 Cross-section view of an air-pruning tray system illustrating the shape of an individual cell, air-pruning and root-branching processes.

plant usually remains constant, a larger root mass results in a larger plant. For the air-pruning trays, plugs/seelings ready for transplanting have cell bottoms full of root tips that are ready to produce new roots as soon as the plugs/seedlings are transplanted. The air-pruned roots are similar to a hair brush, properly oriented downward. It should be emphasized that proper root orientation in the cells/pots/containers is an important factor for future root development after transplanting. However, the non-air-pruned roots are spiraling and tangling, which would hinder the root development after transplanting. It is biotechinically crucial to determine the above mentioned phenomena quantitatively.

Biophysical Interactions and Design Criterion for Proper Trays/Pots/Containers

In a system of utilizing trays/pots/containers it confines a plant-root growth system in a limited space and, therefore, the effects of biophysical interactions on the root formation and plant growth are critically important factors and should carefully be studied based on plant-root physiology. This is because the root formation in the early stage of plant development has profound effects on its future growth in the tray/pot/container and after transplanted into the field or other container, as well as automation of handling and transplanting. Any studies on plant production and automation without full understanding of root development in the early stage are analogous to designing and constructing a building without properly designed foundation. The following important criteria must be satisfied for designing a proper tray/pot/container:

Proper Container-wall Angle

The main reason to cause root-binding is the inherent misconception and improper designs of conventional tray-cells and pots/containers that have smaller closed bottom with drain hole(s) and larger open top which make the container-wall tapered outward toward the top (**Fig. 3**, also, poor stability). As the branched roots encounter the cell/pot wall they turn sideways or upwards resulting in unhealthy root formation. This is because the downward angle at the cell/pot wall is less than 90° while sideways angle is 90° (for round cell) and upward angle is more than 90°. This is the nature of root physiology to lead the roots to least restricted direction, even though, by nature roots would like to develop downward direction. Tests showed that root tips could detect the intersection angle difference of less than 1°. Therefore, this artificially imposed restriction against natural root development due to improper cell/pot wall angle must be corrected for a proper design. Although some tray/pot/container manufacturers have been trying to resolve these disadvantages in plant growth with various means, including adding corners on tray-cells/pots, cutting a larger drain hole at the bottom to get some air-pruning effect or by cutting vertical groove(s) in the cell/pot wall to interrupt the spiraling roots, but the actual improvement is very limited.

Chemical root-pruning uses poisonous chemical such as SPIN-OUT to cover inside of tray-cells/pots/containers to prevent roots from turning or growing as they contact the chemical. This often causes branched roots to stop growing before they reach or after they passed the exponential sections of S-shaped growth curves, and therefore, it does not work as good as proper root air-pruning. In addition, air-pruning is free and has no poisonous effects and works much better than container-applied chemicals that prevent root spiraling. The fundamental problem that needs to be resolved are the intersection angles between the tray-cell/pot/container wall and growing roots.

It is also a common misunderstanding to think that it is harder to remove the plants from tray-cells/pots if the tray-cell/pot wall is tapered inward toward the top, i.e., larger at the bottom and smaller at the top (**Fig. 4**). A simple test would demonstrate that even a plant with large shoot could be removed easily from the open bottom of cells/pot without any damage to the shoot. This is again a natural characteristic of a plant that the plant foliage tends to fold together when the plant is pulled from the bottom and can pass through a small hole without difficulty. This plant characteristic lends itself to an easy dislodging of the plant from the open cell/pot bottom and to the fully automatic transplanting.

For a properly designed air-pruning tray the entire plugs/seedlings can be removed easily from the open bottom by shaking the tray (for injection molded air-pruning trays, the plugs/seedling can also be removed from the top as in conventional trays). No dislodging equipment (such as mechanical dislodger) is required. Another advantage is air-pruning trays filled with plugs/seedlings/cuttings can be shipped in boxes without the fear of plants falling out from the larger top in conventional trays during shipping. This guarantees the quality of plugs/seedlings for supportive plug/seedling production systems in fully automated transplanting operations.

Proper Container Depth and Bottom Opening

These are the important criteria related to effective utilization of exponential portion of S-shaped root growth curve to achieve a superior growth in a shortest period of time. For the conventional or non-air-pruning tray cell, the first root continues to elongate after reaching the cell bottom, avoiding the drain hole, spiraling around at the bottom following the entire S-shaped curve, including the upper portion of S-shaped curve of slow growth and non-growth. Therefore, branching and sub-branching occur at a much slower rate. Most of the branched roots continue to elongate to complete the entire S-shaped growth curves, spiraling around near the cell bottom or forced to grow upwards resulting in unhealthy root formation and root tangling (**Fig. 3**). Effective binding of growth media with roots cannot be achieved causing poor handling and gripping failure.

The growth media in the upper portion of cell is not fully utilized resulting in inferior growth and waste of growth media. If the plugs/seedlings/cuttings/plants are left in the conventional or improper trays/pots/containers for longer period of time, this would result in severe root-binding. This is particularly important for a plug tray because the individual cells are very small. Therefore, the container depth should be determined by the root growth curves of the plant so that the slow-growth and non-growth section of S-curve can be eliminated with a larger open bottom for effective root air-pruning. This means that some conventional tray-cells are often too deep and/or too large for growing superior seedlings resulting in non-uniform growth and waste of growth media.

The effectiveness of root air-pruning in eliminating slow-growth and non-growth stage of the S-shaped curve and promoting plant root branching can best be enhanced by optimizing the depth of tray cell. This process can be simulated using computer logic by relating the root growth rate, cell size, branching and sub-branching rates, in several stages of air-pruned root development. Plug/seedling production can be maximized based on plant species, minimum root development time, cell depth and opening.

Growth Performance of Air-Pruning Trays

Biotechnology in root-air-pruning utilizes plant system characteristics in conjunction with computer-aided optimization of tray-cell/container configuration to achieve a new effective plant cultural practice that should be of considerable benefit to growers and farmers. Superior and accelerated plant growth can be obtained for almost every crop available through the root air-pruning process, including tomatoes, flowers, tobacco, rice, vegetables, grasses, bushes, and trees. However, the public understanding about the process has been limited, even within the fields of agriculture, forestry and horticultural sciences. Contrary to general belief by forestry workers and researchers that tree seedlings require deep tray-cells/pots/containers, many test results showed that air-pruned tree seedlings totally eliminated the spiraling roots, often produce more than one tap root, resulted in faster root establishement with excellent and faster growth even under adverse environmental conditions.

Use Conventional Tray as Air-pruning Tray

The effectiveness of proper tray-cell wall angle can be demonstrated using conventional syrofoam trays. Plant growth performance for tomatoes was studied based on yields and growth results. Conventional styrofoam trays were used as a control while other conventional trays were inverted and detachable screens were attached to the now large open bottom to meet the proper design criterion (**Fig. 5**). The top photograph of **Fig. 5** shows seedlings grown in the conventional tray (left) and inverted conventional tray, modified to be an air-pruning tray (right), six weeks after seeding. The bottom photograph of **Fig. 5** shows the non-air-pruned and air-pruned seedlings (4 left and 4 right, respectively). Superior growth using the modified conventional tray was obvious. The seedlings were transplanted on June 28 in order to minimize the growth variables affecting the growth rate of the plant. No fertilizer was added in this test. Yield data were taken from August 30, when the first tomato was harvested, to October 20, when the first frost appeared. Yield results were analyzed using the data for the average accumulated number of tomatoes and the average accumulated weight of tomatoes. Field observations showed that, in general, air-pruned seedlings grew faster, resulting in larger plants, and bore fruits earlier than non-air pruned seedlings. **Figure 6** shows that the curves for the average accumulated number of tomatoes for air-pruned and non-air-pruned tomato seedlings. The curves show that air-pruned seedlings grew significantly more tomatoes than non-air-pruned seedlings. **Figure 7** shows the curves for the average accumulated weight of tomato harvest from air-pruned and non-air-pruned tomato seedlings. The results indicate that the air-pruned seedlings produced nearly twice the quantity of tomatoes in weight, showing that the tomatoes from air-pruned seedlings were larger.

It should be noted that the air-pruning trays used in this test were simply inverted conventional trays to satisfy the proper tray configuration. The tray depth is deeper than the air-pruning trays designed using computer optimization techiniques. Therefore, the root growth included slow growth

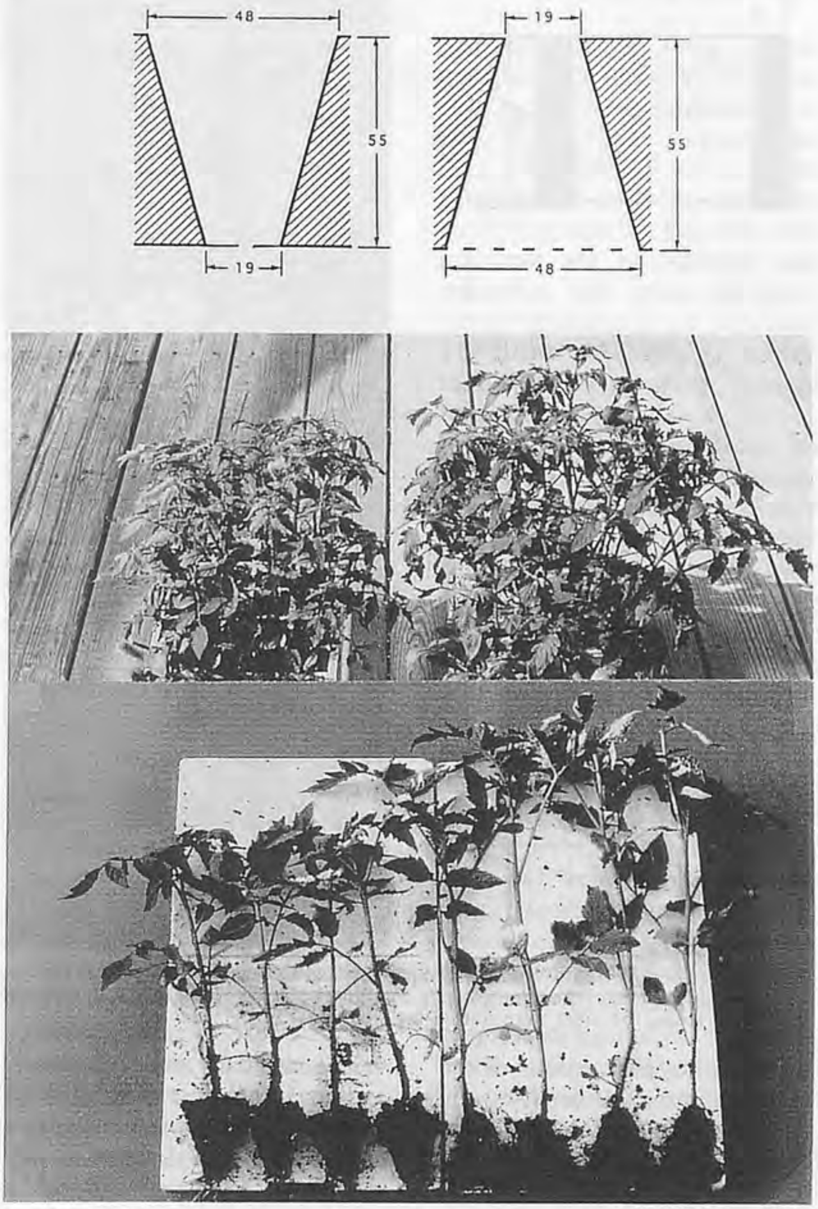

Fig. 5 Top photograph shows seedlings grown in the conventional tray (left) and inverted conventional tray, modified to be an air-pruning tray (right), six weeks after seeding. The bottom photograph shows size comparison of non-air-pruned and air-pruned seedlings (4 left and 4 right, respectively).

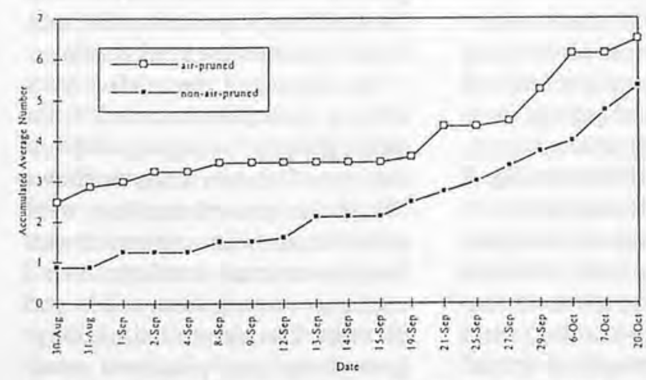

Fig. 6 Accumulated average number of tomatoes versus time.

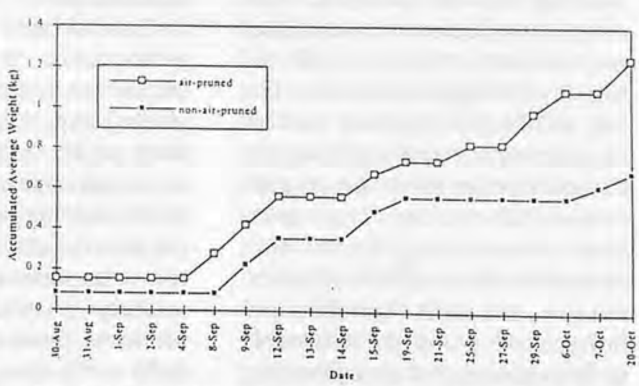

Fig. 7 Accumulated average weight of tomatoes versus time.

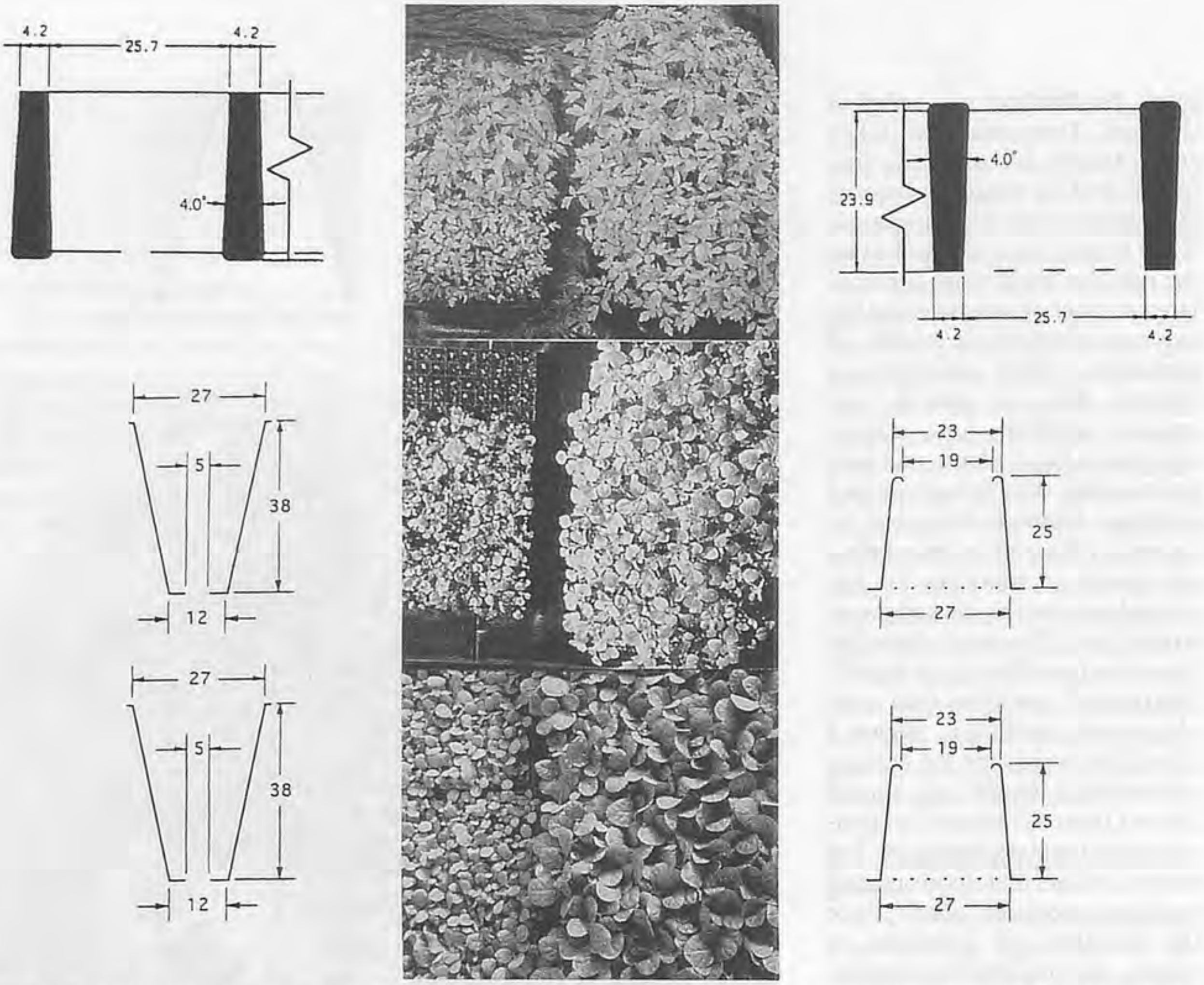

Fig. 8 Growth comparison of tomatoes, impatiens, and tobacco seedlings (from top) grown in conventional trays (left) and air-pruning trays (right) under the same growing conditions 30 days after seeding. For impatiens, the top five rows of tray cells were started from seeds, the other were started from cuttings.

portions of upper sections of the S-shaped curve. Otherwise, the growth performance could be even better.

Properly Designed Air-pruning Trays

The cross-section views of air-pruning tray-cells designed with computer optimization techniques are shown in the right side of **Fig. 8** with their dimensions. The top shows the injection molded air-pruning tray cell and the middle and bottom show the vacuum formed air-pruning tray cells. Both air-pruning trays were designed to be used for tomatoes, tobacco, and most vegetables and floricultural crops and adaptable to fully automated transplanting. The left side of **Fig. 8** shows conventional tray cells (non-air-pruning). The top shows the inverted air-pruning tray using as a conventional tray to compare their growth performance. The middle and bottom show the cross-section profiles of the conventional tray cells that the farmers and growers typically use.

On the basis of the superior performance of the air-pruning concept in terms of growth and yields, large scale growth tests were conducted by selected farmers and growers. Photos in **Fig. 8** show a side-by-side comparison of the growth performance for tomatoes, impatiens, and tobacco seedlings (from top) grown in conventional (non-air-pruning) trays (left) and air-pruning trays (right) under the same growing conditions 30 days after seeding.

For tomatoes, it was amazing to see the growth difference between the conventional tray with the cell-wall 2° tapered out ward toward the top and the air-pruning tray with the cell-wall 2° tapered outward toward the bottom. The growth is much more uniform and the seedlings were at least 3 times larger for the air-pruning trays.

For impatiens, the top five rows of tray cells were started from seeds, the other were started from cuttings. The data analysis shows that the air-pruned seedlings were over 5 times in size compared with the conventional seedlings for all seedlings started from seeds and cuttings. The air-pruned seedlings grew faster and produced much more flowers after they were transplanted. Timing is an important factor for landscape horticulturists. For example, in a northern latitude zone in October, summer flowers, such as impatiens and begonias, are still in full bloom and pretty, yet it's pansy-planting time and garden centers are filled with pansies in a wide range of colors. People can't bear to pull them up now to make room for pansies, but they have to plant those non-air-pruned pansies by November 1 for optimum root development before winter. However, for air-pruned pansies you can easily wait two or more weeks to plant them, and continue enjoying the summer flowers. In the spring air-pruned impatiens allowed faster starting and produced much more flowers throughout the season. The timing advantage is obvious.

Tobacco seedlings shown in the bottom photo were grown by a tobacco farmer who grew over 100 acres of tobacco near Dublin, NC. They were grown in one of his 2 greenhouses, seeded on 3/1/95 in the air-pruning trays and the conventional trays that he had been using. At that time he already seeded his conventional trays in other greenhouses 2 weeks earlier and burned more than $1 000 fuel to maintain the minimum temperature of 65°F for the greenhouse in which tobacco seeds were already germinated and grown to about nickel size. The bottom photo was taken on 3/30/95, 30 days after seeding. The air-pruned seedlings were more than 3 times in size and even larger than non-air-pruned seedling he started 2 weeks earlier. The air-pruned seedlings grew much more uniform and greener and ready for transplanting without mowing practice as used for conventional trays. The root system of an air-pruned seedling was more than 10 times that of a non-air-pruned seedling. The air-pruned seedlings also grew faster and larger with less flowering after being transplanted. At harvest time many air-pruned transplants resulted in producing 2 or 3 tap roots and resulted in higher yields and higher leaf quality.

Air-pruning Trays Facilitate Automation and Improve Aultomatic Transplanting

Transplanting remains a major bottleneck both in greenhouse and field crop production. Labor costs and availability, the high cost of automation, as well as the inherent difficulties of plug/seedling handling with a mechanical gripper, are key problems to be resolved. Information on what transplanting equipment is available, how it works, and how to select equipment to fit into your own system is critical. These problems should be carefully considered before buying a transplanter:

1. Whether the transplanting mechanism is complicated, suffers frequent mechanical breakdown and/or causes plug/seedling damage.
2. Whether a transplanter exhibits erratic singulation — that is, sometimes it grips more than one plant or sometimes it doesn't grip any (missing).
3. Whether a transplanter performs consistently and satisfactorily in terms of plug/seedling feeding, planting depth and planting angle.
4. Whether a supportive plug/seedling production system has been integrated with fully automated transplanting.

At present, several commercial automatic transplanters for greenhouse applications are available and are mainly designed for transplanting plugs from plug trays to flats with larger cells. The basic principle of operation is that the machine dislodges a row of plugs upward with pushers from tray bottom, a row of grippers pick up those plugs, transfer them over the flats, expanding the distance between the grippers, and then push them into the flat cells. The machines are complicated and expensive, and often encounter minor breakdown and missings. The field transplanters remain semi-automatic with manual feeding.

Root air-pruning allows the development of unique trays/containers that lend themselves to automated transplanting systems. Air-pruning trays/containers have open bottoms with detachable screens **(Fig. 4)**. Tray cells are larger at the bottom and smaller at the top to eliminate the inherent disadvantages of traditional tray-cells/containers **(Fig. 3)**. This design also uses the plant shoot characteristic that allows the foliage to fold together to go through a small hole or tube as a plug or seedling is pulled from the bottom or pushed from the top. This plant characteristic lends itself to easy dislodging of plugs/seedlings/plants from the open cell/container bottom. Plugs/seedlings/plants can be transplanted automatically without using any types of grippers, which are often the main cause of problems and unreliability in mechanical transplanters.

The basic principle of fully automated transplanting with an air-pruning tray is illustrated in **Fig. 9**. During the transplanting process, the detachable screen bottom is removed and the air-pruning tray becomes an integral component of the fully automatic transplanter. The individual plugs/seedlings are pneumatically or mechanically removed downward through the tray cell. A vacuum system or mechanical pusher dislodges the plug/seedling from the open bottom or top of

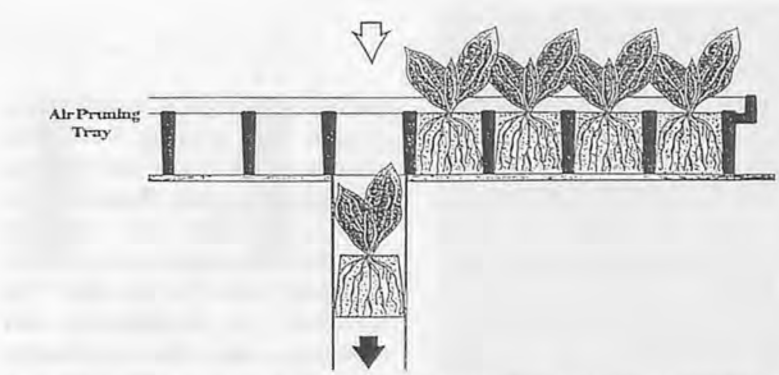

Fig. 9 The basic principle of a fully automatic transplanter with an air-pruning tray.

the tray cell. As the suction or mechanical force pulls or pushes the plug/seedling downward the leaves fold to pass through the cell and drop tube without any damage to the leaves. An impulse vacuum system was developed for simple and effective vacuum generation to dislodge and plant the plug/seedling in one simple operation. The downward moving plug/seedling can reach a velocity of 20 ft/sec, which achieves a good bonding between the root system and growing media in a minimum time.

A major benefit of removing the plugs/seedlings from the bottom of the trays is that much larger seedlings can be accurately transplanted than with other automated transplanters that grip seedlings from above (even with a vision system) and can entangle or damage leaves and stems. **Figure 10** shows the impulse vacuum type fully automatic greenhouse transplanters for transplanting pots (upper) and flats (lower). **Figure 11** shows an impulse vacuum type fully automatic two-row field transplanter.

Conclusion

The importance of properly designed trays/pots/containers based on plant-root physiology and root-air-pruned plant production has been demonstrated. This is especially critical in greenhouse operations due to their tray/flat/pot/container cultural practices. Properly designed air-pruning trays/pots/containers eliminated root-binding for proper and accelerated root formations, resulting in superior and faster plant growth both in trays/pots/containers and after the plants are transplanted. Clear understanding of the root-air-pruning process and its proper applications to tray/flat/pot/container grown plugs/seedlings/plants would significantly increase yields and crop quality, and promote full automation of transplanting operation. This would result in savings on labor, fertilizer, growth media, water, and heating fueld consumption, and greatly increase the utilization factor of greenhouse facilities by shortening the plant growth periods thus increasing the utilization cycles of greenhouses. Traditionally, agricultural and forestry fields are very conservative in accepting new methodologies even when the clear-cut advantages have been demonstrated. Technology transfer from research to market usually takes much longer as compared to industrial sectors. Therefore, the public awareness on how the simple biotechnology and computer methodology can bring revolutionary effects on green industry is of utmost importance. Along with these direct advantages, indirect advantages on easy automation, energy and environmental conservation and reduced water and air pollution should not be ignored.

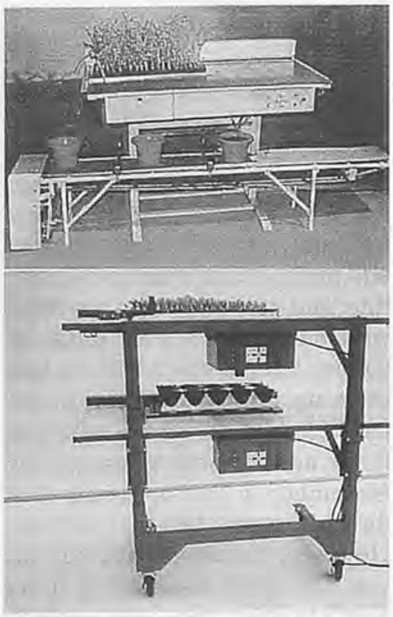

Fig. 10 Impulse vacuum type fully automatic greenhouse transplanters for transplanting pots (upper) and flats (lower).

Fig. 11 Impulse vacuum type fully automatic two-row field transplanter.

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(Continued on page 56)

Agricultural Mechanization in Cambodia: a Case Study in Takeo Province

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Abstract

This study is based on a survey of 100 farmers from 2 different districts in Takeo province, Cambodia. This was conducted through personal interviews of the farmers from January, 1995 to May, 1995. The aim of the study was to examine the present status of agricultural mechanization in Takeo province and compare the yields, labour use and cropping intensity on rainfed and irrigated farm plots of different groups of farmers in the survey areas. The farm plots were categorized as: i) rainfed only; ii) irrigated with traditional farm tools; and iii) irrigated with engine-driven pump. The farmers were classified into three groups, according to farm size i.e. i) small scale farmers (average 0.8 ha); ii) medium-scale farmers (average 2 ha); iii) large-scale farmers (average 4.5 ha).

The present status of agricultural mechaization in Takeo province is still traditional. Human labour and animal power are the major power sources in the province.

Some engine-driven pumps and threshers are being used in Takeo province, especially in the southern part. A small number of 4-wheel tractors are used mainly for land preparation and transportation.

Introduction

Cambodia is a country which occupies the southern part of Indochina and borders with Thailand, Laos and Vietnam. The country has a land area of 181 035 sq km of which nearly 20% is arable (1). A central plain, drained by the Boung Tounle Sap (Great Lake) and the Mekong and Basac river systems, contrasts with the Cardamon mountains in the southwest of the country and the Dangrek mountains in the north along the Thai border.

Agriculture is the chief industry in Cambodia. At present, the total population of the country is 9.13 million according to the statistics in 1993 (2). Its development must basically depend on agriculture. About 90 percent of the population is engaged in agriculture. Rice is the most important crop the average yield of which is about 1 200 kg/ha.

Cambodian agriculture is still traditional. Mechanization, or other inputs such as improved seed varieties, fertilizers and pesticides are still limited. Human power and draft animals are the main power resources in agriculture in the country.

Study Objectives

1. To determine the present status of agricultural mechanization in Takeo province, Cambodia.
2. To compare yields, labour use and cropping intensity of paddy fields by farm size.
3. To understand the effect of agricultural machinery on yields, labour use and cropping intensity of paddy fields by farm size.
4. To estimate and compare the family incomes by farm size.

Methodology

This study was conducted in Takeo province in the southern part of Cambodia and considered the relationship between the level of mechanization, farm size and agricultural productivity.

Due to the difficulties of access to the study sites, lack of information from the Department of Agriculture and other agricultural offices in various district in Takeo province, only 2 of 9 districts were selected: Prey Kabas district, towards the north and Kirivong district, southern part of the province.

Paddy is the major crop grown in Takeo province. There is a wide variation in cropping practices from one area of the district to another where floating paddy, early paddy, medium paddy and late paddy are all grown.

The target groups of this study were: i) small-scale farmers with average farm size of 0.8 ha; ii) medium-scale farmers with average farm size of 2 ha; iii) large-scale farmer with average farm size of 4.5 ha. Fifty farmers from each district were selected in a random sample for this study.

The questionnaire was divided into two parts. The first part was for general farm information and the second part was for each plot of a farmer on a per crop basis. Most of the farmers have low educational level and they did not keep any records. Therefore, most of the data collected were based mainly upon the farmers' recollections.

The information and data were subjected to statistical analysis. Differences of the mean values were tested by the Student t-test using the SPSS (Statistical Package for the Social Science) programme.

Results and Discussion

Socio-economic Characteristics

Among the household surveyed, 22% were in the small-scale category; 57% in the medium-scale group; and 21%, large-scale farm group (3).

Most of the farmers in the sample survey could read or write. Some 20% of the farmers in Prey Kabas and 10% in Kirivong did not attend formal schooling (3).

Respondents in all survey areas reported that the farm size was similar to the other villages in Takeo province as the Government distributed land to farmers depending on family size starting in 1989. Farmers have since been allowed to increase their own land on new areas, such as fields abandoned during the war and reclaimed areas. However, they have to clear such move with the Village Committee and Sub-district first (3).

Because of refugees from the Thai border area, newly married families and migration of people from one area to another, the holding sizes have changed in recent years.

During discussion with a land title officer, it was reported that privately-owned land was not allowed until 1989. Before that time all the land belonged to the Government. When the Government distributed land to farmers in 1989 the average holding size per farm person was 0.2 ha (3).

Generally, most of the farmers in the selected areas owned their farms. Farmers have a right to sell, rent, share crop or give some part of their own land to a son or daughter to manage individually, when he or she gets married. About 5 percent of the total farmers in the survey areas reported that they do not own any land*. Instead this proportion of farmers rent farms or perform share cropping per crop season or years. Renting a farm, or share cropping is done in any of the following terms and conditions: i) the owner takes a price without considering the yield; ii) the owner takes a price by considering the yield; or iii) the owner provides seed and fertilizer and takes 50% of the harvest.

Shared cropping systems are not very productive, because the tenant or share cropper is not interested in increasing the crop yield.

During interviews with the farmers, it was noted that rice yields were low as most of them are poor, some areas suffered flood or drought, insect pests and disease problems. Some farmers, who are widows or widowers, old, sick or poor, derive low income from the farm because of lack of human power, animal power and farm tools. Therefore, they sell part or all of their own land to richer farmers. When their holdings are sold (as some 5 percent of families in the province sell their farms after the Government provided them the land [3]), these dispossesed farmers either move to urban centers to look for work as factory workers, taxi drivers, market vendors, etc. Some stay in the village to engage in fishing or work daily wage earner.

No farmers in the survey areas mad bank loans to finance their farm expenses. For buying machine or fertilizer, farmers rather borrowed money from their relatives or from rich farmers. The interest rate is high compared to a bank. The range of interest rate was from 5 to 25% per month or per cropping season. Most of the farmers in the survey area preferred to buy fertilizer for credit from a contractor and repay in kind or paddy from the harvest. Normally, one bag of fertilizer sells for 120 kg of paddy (3).

Farm Practices and Status of Farm Mechanization

Takeo is bordered by Vietnam to the south, Kandal province to the east, Kampong Speu province to the north and Kampot province to the west. The entire province is divided into 9 districts and one provincial town. The total population in Takeo in 1990 was about 620 700. The average population density of this province is 178.3 person/sq km compared to about 50 person/sq km in the whole country (4). Average temperature was 26°C with the highest about 40°C during the month of April.

In Takeo the main rainy season occurs in the period from Pisak (May) to Kadic (November) with September and October being the wettest months. The dry season is

*Source: Personal communication with the representative of different villages in the survey area.

from the beginning of Kadic (November) to end of Chet (April). Rice is the most important food grain in Takeo. Other crops grown are corn, sweet potatoes, cassava, peanuts, mung beans and sugar cane.

Farm tools — Farm tools, as in other areas in Cambodia, are mostly traditional such as field knife (grass cutting knife), hoe, sickles, animal plows, animal comb harrows and ox-carts. Most of the farm tools are manufactured by local blacksmiths and marketed locally. Because of local production, the prices of farm tools are low. The existing farm practices in Takeo province are shown in **Table 1**.

Table 1. Existing Farm Practices in Takeo Province

Operation	Power Source	Implements/Methods of Application
1. Tillage	a. Human	a. Hand tools
	b. Animals	b. Traditional plow with mildsteel share
	c. Tractor	c. Disc plow, disc harrow, rotovator
2. Pulverizing and Levelling of the soil	a. Animals	a. Comb harrow
3. Sowing and Planting	a. Human	a. Broadcast method
		b. Nursery seedbed and transplanting
4. Irrigation	a. Human	a. Swinging bucket, tripod water shovel, pedal pump
	b. Engine	b. Low-lift pump, centrifugal pump
5. Fertilizing	a. Human	a. Broadcast method
6. Manuring	a. Human	a. Basket
	b. Animals	b. Ox-cart
7. Weeding	a. Human	a. Hand pushed weeder, hand tools, spraying, broadcasting
8. Spraying	a. Human	a. Hand sprayer, type made of bamboo or metal tube, knapsack sprayer
9. Harvesting	a. Human	a. Sickle
10. Threshing	a. Human	a. By beating against wood, by walking over the swath
	b. Animals	b. By walking over the spread harvested crop
	c. Engine	c. By tractor driving over the spread crop, by mechanical threshers
11. Winnowing and drying	a. Human	a. Shaking against air. Drying is done by spreading the swath on the field in the sun, by spreading the paddy on a mat or other flat surfaces

Table 2. Mechanization Status in the Study Area

Item	Prey Kabas and Kirivong District			
	Small-scale farmer	Medium-scale farmer	Large-scale farmer	Total
No. of households	22	57	21	100
Average farm size (ha)	0.8	2	4.5	—
a) No. of traditional water pumps				
Tripod water shovel	6	21	5	32
Pedal pump	3	0	0	3
Swinging bucket	11	24	5	40
b) No. of draft animals	0	195	36	231
c) No. of draft animal implements				
Plough	3	60	19	82
Harrow	1	56	18	75
Ox-cart	0	52	14	66
d) No. of tractors	0	0	4	4
e) No. of engine-powered pump				
Chinese engine driven	4	11	5	20
American engine driven	2	7	3	12
Thai engine driven	1	4	2	7
f) No. of threshers	0	0	2	2

Draft animals — Most of the farming operations are carried out by using traditional methods which rely on human labour and/or animal power. Nearly all land preparation is carried out by oxen or buffaloes. The plow or comb harrow is pulled by a pair of animals. One pair of oxen/buffaloes can be purchased for 900 000-1 150 000 Riel** (US$360-460) and can plow 0.15-0.2 ha per day. There are presently about 179 thousand draft animals in the province (3).

The advantages that animals have are their low operating cost, manure production, reproduction, and a food source when necessary. The disadvantage is the time required to cultivate (7-10 person days/ha) and the time taken for other tasks. Animals can only work a limited number of hours per day and have to be fed, vaccinated, watered and housed.

Tractors and power tillers — After 1979, the Government imported agricultural machineries from Russia and other Socialist countries in order to help Cambodian farmers increase their food production and promote agricultural mechanization. Around 100 tractors were distributed to Takeo province by the Department of Engineering in the period between 1979 to 1989 (5). During that time all tractors and other machineries belonged to the Government. Normally a tractor was used only 3 or 4 months per year in land preparation, especially in March to May or June. For the rest of the time it was used for transportation.

Because of lack of technicians, the problem of land - mines, shortage of spare parts, problems in Russia and other Socialist countries, most of these machines have deteriorated since 1987.

After 1989, the Government started privatization of many Government enterprises. Farmers started to have a right to buy new agricultural machineries from private companies or old agricultural machineries from the State. Eighty percent of the latter were bought by individual farmers and 20% by groups (6). Individual owners used their tractors on their own farms and contract for the other at 30 000-50 000 Riel/ha, depending on the locality. The price of fuel at the time of the study is 800 Riel/ℓ and the oil was 1 700 Riel/ℓ. Work rates during plowing

**1 US$ = 2500 Cambodian Riel, during January-May, 1995.

ranged from 0.5-1.5 ha/h for a Russian tractor of 60 kW. The smallest field size where the large tractors are used is approximately 0.5 ha. **Table 2** shows the mechanization status in the study area by farm scale.

In Takeo province, large tractors have been used mainly in the southern areas, e.g., Traing, Koh Andet, Borey Chulsar and Kirivong districts, where there is a lack of other power sources such as the floating rice areas, and the dry land irrigated areas. Annual usage is now about 200-250 ha/year with each machine consuming up to 10-15 ℓ/h of diesel fuel for a Russian tractor of 50 kW***.

In Cambodia, around 1 300 power tillers have been imported from Thailand, Japan and Peoples Rep. of China. The engines range in size from 8 to 10 kW (6). In Cambodia power tillers are not very popular as in other Asian countries. Most of the Cambodians believe that their effectiveness is not very different from animal power and requires much more energy to operate.

Pumps — In Takeo province most of the farm irrigation is carried out by using traditional farming tools such as swinging bucket, pedal pump, etc. Engine-powered low-lift centrifugal pumps are now being used in the province. They became popular since 1990, when a lot of floating paddy fields were changed to grow early paddy varieties in the dry season.

The majority of engines for the pumps are Thai, Chinese or American made and pumps have been imported as well as manufactured locally. At present about 2 400 small engine-driven pumps are in use in this province (2). The engines range in size from 3 to 5.2 kW. These machines have a pumping capacity of approximately 100 ℓ/min and use approximately 0.4 ℓ/h fuel.

***Source: Personal communication with a representative of Department of Agricultural Engineering, Ministry of Agriculture, Cambodia.

Fig. 1 Local-made centrifugal pump with Thai-made engine.

All the farmers in the survey area preferred using an engine driving a local-made centrifugal pump. The advantage is that the farmer can use the engine for many purposes, e.g., the engine can drive a boat. The disadvantage is that the efficiency of this pump is low (3) **(Fig. 1)**.

Other machines — Threshers and rice mills are used in Takeo province, hence it is possible for the farmers to get rice bran for raising pigs, chicken etc. and collect rice husk for fuel purposes after milling. Most of the threshers have been used mainly in the southern part of the province, where labour is scare during the harvesting period. Because the southern part of the province is bordered by Vietnam, mostly Vietnamese threshers are in use.

Vietnamese threshers trailed by a tractor were modified by Vietnamese manufacturers to self-propelled ones with a four-wheel drive system. This allows a thresher to get into the fields more easily for on-site custom operations **(Fig. 2)**.

Fig. 2 Vietnamese rice thresher in use threshing paddy in the field.

Analysis of the Study

Yield of Paddy

The average yields of paddy varieties/ha is given in **Table 3**. There were significant differences for all scale farms. As expected the yields of irrigated fields were higher than the those of rainfed fields as the availability of water for the crop was high (3).

The yields on pump-irrigated paddy fields were also higher than those using traditional implements for irrigation irrigated fields as the availability and the quantity of water was more assured for pump irrigation, which was not always possible with traditional pumps.

Cropping Intensity

The cropping intensity of farmers in the survey area was very low compared with other Asian countries.

Table 3. Average Yield of Paddy (Unit: kg/ha)

Category	Items	Small-scale farmer (A)	Medium-scale farmer (B)	Large-scale farmer (C)
1. Rainfed	No. of farmers	10	32	12
	Mean yield	1 090	1 233	1 142
	Stand. deviation	578	539	281
2. Irrigated with traditional water pump	No. of farmers	15	20	—
	Mean yield	1 490	1 759	—
	Stand. deviation	563	1 223	—
3. Irrigated with engine-driven pump	No. of farmers	13	68	22
	Mean yield	2 290	2 912	2 641
	Stand. deviation	899	1 250	1 435

Difference in yields between:
1) 1A and 3A Significant at 99% confidence level.
2) 2A and 3A Significant at 99% confidence level.
3) 1B and 2B Significant at 95% confidence level.
4) 1B and 3B Significant at 99% confidence level.
5) 2B and 3B Significant at 99% confidence level.
6) 1C and 3C Significant at 99% confidence level.

Table 4. Average Cropping Intensity, by Farm Scale

Items	Small-scale farmer (A)	Medium-scale farmer (B)	Large-scale farmer (C)
No. of farmers	22	57	21
Mean crop. intensity	106	117	109
Stand. deviation	13.4	18	22.7

Difference in cropping intensity between A and B columns was significant at 99% confidence level.

Table 5. Labour Utilization (Unit: man-day/ha)

Category	Small-scale farmer (A)	Medium-scale farmer (B)	Large-scale farmer (C)
1 Rainfed	78.9	72.4	64.3
2 Irrigated with traditional water pump	123	121.7	—
3 Irrigated with engine-driven pump	104.2	112.3	92.3

Difference of labour used for paddy farm per ha between:
1) 1A and 2A Significant at 99% confidence level
2) 1A and 3A Significant at 95% confidence level
3) 2A and 3A Significant at 95% confidence level
4) 1B and 2B Significant at 99% confidence level
5) 1B and 3B Significant at 99% confidence level
6) 3B and 3C Significant at 99% confidence level
7) 1C and 3C Significant at 99% confidence level

Table 6. Average Family Incomes, by Farm Size Category (Unit: 1 000 Riel)

Items	Small-scale farmer (A)	Medium-scale farmer (B)	Large-scale farmer (C)
1) Total net farm income	594	1 654	2 272
*Income from paddy	322	1 323	1 775
*Income from livestock	87	154	43
*Income from vegetables	9	82	438
*Income from fruits	48	12	10
*Income from fishing	127	83	6
2) Interest	12	6	17
3) Net farm earnings	582	1 647	2 255
4) Non-darm income	69	47	149
5) Family earnings	650	1 694	2 404
*Family earnings per capita	107	276	335

Difference in total farm income between:
1) A and B significant at 99% confidence level.
2) A and C significant at 99% confidence level.

Difference in total net farm earning between:
1) A and B significant at 99% confidence level.
2) A and C significant at 99% confidence level.

Difference in total non-farm income between:
1) B and C significant at 95% confidence level.

Difference in family earnings between:
1) A and B significant at 99% confidence level.
2) A and C significant at 99% confidence level.
3) B and C significant at 95% confidence level.

Low cropping intensity in the large-scale farmer group was due to the fact that, in the present conditions in Cambodia, farmers cannot adequately manage this size of farm (3).

For small-scale farmers, cropping intensity was lower than other farm sizes as they could not afford water to irrigate their farm due to water sources being far from the farm and not having enough money to hire engine driven pumps to irrigate the farm.

In rainfed farms, it is difficult to increase cropping intensity. In some areas farmers cannot plant their crop at the proper time, as the soil is hard and they also use draft animals for land preparation, hence they have to wait for rain until there is sufficient moisture in the fields and they become sufficiently soft to plow.

Labour Utilization

The distribution of labour for the production of paddy varieties is shown in **Table 5**. Labour utilization was higher for irrigated fields compared to rainfed fields. The fields, irrigated with traditional implements, required maximum labour. The quantity of irrigation water and the labour utilization depends on the availability of the water and its sources.

In both, rainfed and irrigated paddy fields with pumps, large-scale farmers utilized less labour because most of them used tractors for land preparation on their farms (3).

There was a significant difference in irrigated paddy fields with pumps between medium-scale farmers and large-scale farmers. On pump-irrigated paddy fields, medium-scale farmers utilized more labour, because they used more power in land preparation and threshing. For small-scale farmers, the utilization of labour was less than the other scales as the yield of paddy was very low and they could not borrow or rent animals to plow their own farm from relatives or other farmers on time (3).

Family Income

From **Table 6**, the family earnings of large-scale farmers had the highest value of 2 404.08 thousand Riel/year, followed by the family earnings of medium-scale farmers with 1 694.28 thousand Riel/year. Next was the family earnings of small-scale farmers with only 650.25 thousand Riel/year.

Low income of the small scale farmers was due to the fact that they do not have enough draft animals for use in land preparation, and non-farm incomes were also low.

There were significant differences for all scales of farmers. The income of large-scale farmers were higher than the other farmers, because they have large farm, and derive higher income from the commercial work, such as hiring out their pump, thresher, and tractor to other farmers.

Conclusions

1. The present status of agricultural mechanization in Takeo province, Cambodia is still traditional where human labour and animal power constitute the major source of farm power.

2. About 47 tractors work in Takeo province, especially in the southern of the province and are

mainly utilized for land preparation and transportation. The size of paddy fields are still small, being less than 0.5 ha per farm for irrigated fields. Small engines connected with a local made centrifugal pump and Vietnamese threshers are in use in the province.

3. The yield of paddy per hectare was higher in the irrigated fields than in the rainfed fields. The yields of pump irrigated fields were higher than that of traditional irrigation implements.

4. Labour utilization was higher in the irrigated fields compared to rainfed fields. The fields irrigated with pumps of medium scale farmers required most labour because they use more power on land preparation and threshing.

5. For all groups of farmers, the cropping intensity was highest for the medium scale farmers at 117%. However, this cropping intensity was very low compared to other Asian countries.

6. From the total average family earnings of different farm scales, the family earnings of large scale farmers were higher than the other farmers. In particular, they had more income from paddy, vegetables and non-farm activities. Family earnings per capita were also largest on the large scale farms.

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Loss Assessment in Traditional and Modern Methods of Processing Cassava into "Gari"

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Abstract

Experiments were conducted to quantify the losses in *gari* using local and modern methods of processing.

An average loss of 5% in cassava occurred at the peeling stage for both local and modern centres. The grating process recorded an average loss ranging from 3 to 8%. The highest loss of 8% occurred at the local centre as against 3.8% in the modern centre where improved machines were used.

The losses at the dewatering stage ranges from 3 to 5% while the sifting process losses ranged from 3 to 4% for modern centres and between 4 to 5% for local Cassava Processing Centres. The total average losses in gari processing for modern centres was 17% while that for local centres was 23%. A garification rate of 0.66 and 0.50 was established for the modern and local processing centres, respectively.

Introduction

Gari, a granular food product from cassava (*Manihot esculenta*) is a major source of calories for millions of people in the humid tropics. Gari is processed by the accomplishment of a set of unit operations. These are: peeling, washing, grating, fermenting, dewatering, sieving and frying. Harvesting, reception of tubers from place of supply, cooling of the fried or roasted gari, and packaging of the final product are other complimentary operations that could be indicated. These operations are mainly carried out manually under rural conditions. This is not only tasking and ineffective, but also time-consuming and, therefore, inefficient. Because of the handling and processing conditions, they often result in a very poor quality of the products. In addition to the high labor intensity and drudgery in the manual operation, the conditions during processing are generally unsanitary and unwholesome (Olufemi, 1984).

In response to a great demand for appropriate technology to enhance the processing conditions of cassava, efforts have been geared towards developing equipment for the various unit operations. Recently, different machines have been designed and manufactured to increase production and processing of cassava into gari and other products. Such processing machines include; cassava harvesters, cassava graters, cassava pressing machines, mills, sifters and fryers (Odigboh, 1983; Igbeka *et al*, 1992; Emesih, 1995). Recently, Sreenarayanam *et al* reported the lye-peeling of cassava (Sreenarayanam *et al*, 1995).

The objective of the study reported in this paper is to quantify the losses in processing cassava into gari. This is intended to provide a means of reducing the losses as well as modifying some of the machines used in the processing.

Materials and Methods

The machines selected for the processing of gari were; grater (diesel and electric), press (hydraulic and screw jack), and sifter (mechanical and manual). These were chosen after a detail survey of cassava processing machines in Oyo State, (Davis, 1991; Kufeji, 1992). The peeling and frying process were carried out manually using knives and frying pans, respectively.

Tests were carried out in six processing centres classified into modern and local centres. These were Moniya, Ojoor and Iwo Road as modern centres, while Abdina, Mokola and Odo-ona as local centres. The set of equipment used for the centres are shown in **Table 1**. The data were collected for each of the processing stages as outlined below.

Peeling Process

Table 1. Set of Equipment Used at Each Processing Centre

Centres	Description	Operations/Equipment Used				
		Peeling	Grating	Pressing	Sifting	Frying
Odo-ona	Local	Knives	Diesel graters	Screw jack press	Traditional	Frying pan
Abadina	./	./	./	./	./	./
Mokola	./	./	./	./	./	./
Moniya	Modern (IITA) (model machines)	./	Electric graters	Hydraulic press	Mechanical sifter	Frying pan (improved with less smoke)
Ojoor	Modern	./	./	./	./	./
Iwo Road	./	./	./	./	./	./

Cassava tubers were weighed in a standard bag of negligible weight. After peeling with knives, the cassava flesh attached to the peels were separated and their weight taken and recorded. The percentage loss at this stage was calculated as:

$$X = \frac{W_2}{W_1 - (W_2 + W_3)} \times 100 \quad ...(1)$$

Where,

X = Percentage loss during peeling

W_1 = Initial weight of cassava tubers (kg)

W_2 = Weight of cassava flesh attached to the peels (kg)

W_3 = Weight of peels (kg)

Grating Process

The washed tubers were grated inside a grater and the resulting pulp was neatly packed and the weight noted. The percentage loss at this stage was found using the formula below:

$$Y = \frac{W_4 - W_5}{W_4} \times 100 \quad ...(2)$$

Where,

Y = Percentage loss of cassava at grating stage

W_4 = Weight of cassava after washing (kg)

W_5 = Weight of pulp collected after grating (kg)

Dewatering Process

The standard bag containing the pulp was placed under either a hydraulic press or screw jack press for dewatering. The pulp that came out as the bag was being pressed and in some instances spillage as a result of either a broken bag or poor handling was collected and the weight taken. Percentage loss of pulp was found using the following formula:

$$Z = \frac{W_6}{W_7} \times 100 \quad ...(3)$$

Where,

Z = Percentage loss at dewatering stage

W_6 = Weight of pulp loss during pressing (kg)

W_7 = Weight of pulp in the bag before starting the pressing (kg)

Sifting Process

The caked pulp was weighed and then broken with hands and sifted in a sieve locally made from palm frond ribs or wire mesh. For the modern centres mechanical sifters were used. Percentage loss at this stage was calculated using the following formula:

$$A = \frac{W_8 - (W_9 + W_{10})}{W_8 - W_{10}} \times 100 \quad ...(4)$$

Where,

A = Percentage loss at sifting stage

W_8 = Weight of dewatered pulp (kg)

W_9 = Weight of sieved pulp (kg)

W_{10} = Weight of waste fibres (kg)

Frying Process

The sieved cassava pulp was poured in sufficient quantities into the frying pan on fire to reduce the moisture content of about 50-60% (Igbeka J.C., 1992) to a considerably low level of 11-13%. The percentage loss at this stage was calculated using the following formula:

$$B = \frac{W_{11}}{W_{12}} \quad ...(5)$$

Where,

B = Percentage loss at frying stage

W_{11} = Weight of spilled or burned or out of standard quality gari (kg)

W_{12} = Quantity of gari fried (kg)

Total Loss

The total loss was calculated by the addition of all the losses in Equations (1)-(5).

For all the processes, the samples were replicated four times and the average taken. Most of the processes were performed by women except for the pressing process wherein some centres like Ojoor and Abadina where men were involved.

Garification Rate

The garification rate was calculated as the ratio of the quantity of gari over quantity of fresh cassava tubers.

Results and Discussion

The percentage losses in cassava at each stage of processing for all the observed centres is presented in **Table 2**.

Losses at the Peeling Stage

The highest peeling percentage loss occured at Mokola and Ojoor Centres with values of 5.7% and 5.3%, respectively. Lower percentage losses at 4.9% was recorded at Moniya **(Table 2)**. In all the centres, knives were used in peeling cassava tubers. Therefore, the

Table 2. Percentage Losses of Cassava at Various Stages of Gari Processing for the Observed Centres

Centres	Percentage Losses					Total Loss
	Stages					
	Peeling	Grating	Dewatering	Sifting	Frying	
A. Local Centres						
1. Abadina	5.2	8.1	4.6	5.4	—	23.3
2. Mokola	5.7	7.5	5.1	4.6	—	23.0
3. Odo-ona	5.0	7.9	5.0	5.3	—	23.2
B. Modern Centers						
1. Moniya	4.9	4.7	4.5	3.5	—	17.6
2. Ojoor	5.3	4.8	3.9	4.1	—	18.1
3. Iwo Road	5.1	3.8	4.7	3.7	—	17.3

difference in losses is due to the experience of the women peeling the tubers in ensuring minimum loss. The irregular shape and sizes of cassava tubers makes peeling difficult such that when handled by inexperience persons, results in high losses.

Losses at the Grating Stage

At the grating stage major losses were observed in the local centres. Lower percentage losses were recorded in the modern centres. As can be observed from **Table 2**, the average percentage losses of 8.1, 7.5, 7.9 was recorded at Abadina, Mokola and Odo-ona Centres, respectively. This is higher than 5.1%, 4.8%, 3.8% recorded for Moniya, Ojoor and Iso Road which are modern centres. The sharp difference between these centres are largely due to the mode of collecting the pulp. Although the grating machines were the same for the centres, a cemented pit is used as a means of collecting the mash from the exit chute for the local centres. This allows the mash to stick to the crevices and rough surfaces of the cemented pit. The use of a rectangular open box easily rolled from the exit chute of the grating machine, in collecting the pulp ensures that none of the pulp is left inside it since it gives room for washing the pulp out into a jute bag. The housing unit of the grater and mode of collection of the mash in the modern centres is more efficient than that obtained in local cassava processing centres.

Losses at the Dewatering Stage

Much mash water (a solution containing some incompletely soluble mash particles), was removed from the pulp. As can be seen in **Table 2**, the average losses of 4.5, 3.9, 4.7 occured for the modern centres, while 4.6, 5.1, 5.0 were recorded in the local centres. These percentage losses could not be the actual moisture content lost during dewatering due to the presence of mash particles which are collected precipitates as sediments (sedimentation). Overall, the losses at this stage were not significantly different in all the centres observed. It can, therefore, be concluded that the pressing machines available are efficient both for the local and modern centres.

Losses at the Sifting Stage

The local centres recorded higher percentage losses at this stage than the modern centres observed. This is largely due to the machine or method used in the sifting. For the modern centres, a mechanical sifter with wire mesh (dimensions 75 mm × 56 mm × 17 mm) is used for sifting whereas a local sieve made from palm fronds is used in the local centres. Thus the modern cassava processing centres recorded average losses of 3.5, 4.1, 3.7 (Moniya, Ojoor, Iwo Road, respectively). This is less than those recorded in local centres which were 5.4, 4.6, 5.3 for Abadina, Mokola and Odoba, respectively.

Losses at Frying Stage

The losses at this stage could not be recorded accurately due to the attitude of the persons performing the operations. In all the centres observed, the operators were very careful at this stage and as a result, negligible losses were recorded. The only point of interest was the hazard of smoke which was more pronounced in the local centres than the modern ones.

Total Loss

The average total percentage losses of cassava at the local centres was 23 while that for the modern centres was 17. This difference was largely due to types of processing machines used. In the local centres, traditional methods and less efficient processing machines were used. The lower percentage losses observed in the modern centres is a reflection of the improved methods and machines for processing cassava into gari.

From this work, a relationship between the amount of gari after frying and the weight of fresh cassava tubers was established as:

$$W = W_0.K$$

Where,

W = Weight of gari after frying (kg)

W_0 = Initial weight of cassava tubers (kg)

K = Constant (garification rate)

The experiments established the average value of K for modern centres as 0.66 and that of the local centres as 0.50. It is, therefore, possible from this study to predict the quantity of gari that can be obtained from a given quantity of tubers at a particular centre. The constant K can also be used to predict the likely performance of a set of cassava processing machines. The higher the value of K the more efficient are the machines. Therefore, in the design or modification of cassava processing machines, the aim should be at increasing the value of K.

Conclusions

The following conclusions were reached in this study:

1. The total average losses of cassava at peeling, grating, dewatering sifting stages were 5.3, 7.8, 4.9, 4.1%, respectively, for local centres while in the cases of modern centres were 5.1, 4.4, 4.4 and 3.9%.
2. The total average losses in gari processing for modern centres was 17% while that of local centres was 23%.
3. A garification rate of 0.66 and 0.50 was established for the modern and local processing centre, respectively.

Recommendations

From the observations on this work and considering the growing importance of cassava, the following recommendations are made:

1. There is need for an efficient peeling machine.
2. The design of the housing unit of grating machines should be improved to reduce the loss of mash. The local method of collecting pulp from cemented pit be replaced with a rectangular built wheel wooden box, easily rolled off from the cute after grating.
3. An efficient sifting machine or better sifting method should replace the local palm frond sifter to minimize loss.
4. The available frying techniques should be improved upon in order to reduce the hazard of smoke and intense heat.
5. More experiments should be conducted in other places for comparison.

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Post-harvest Processing and Technologies Used by Oman Date Farmers and Factories

by
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Abstract

Date is one of the major fruit crops grown in Oman. Farmers adopt various methods and equipment to preserve harvested dates. Post-harvest operations carried out by farmers range from carrying of dates in date palm frond and plastic containers through open-air, sun-drying to room temperature and refrigerated storage. One date variety, "mabsli", is heat-treated before drying. Drying floors used are the ground, simple platforms, flat-roof tops and open containers. The operations carried out at the factories follow normal essential operations in a date packaging plant involving fumigation, cleaning, sorting, drying, heat treatment, grading, packaging and storing. Two major factories which started operations in 1976 are operating with old equipment. Information and data on the range of operations and the methods and equipment used are presented. Process charts developed for the operations are also given. Abundant solar energy is available in Oman and there are good prospects of applying solar technology in post-harvest operations. Innovative post-harvest technologies for applying solar energy in ripening, heat treatment, drying, fumigation and cold storage are outlined.

Introduction

Date palms are among the most important food crops in the Sultanate of Oman. The Sultanate, a major date producing country in the Arabian Peninsula, has 23 000 to 25 000 ha of land planted to date palm constituting 39% to 43% of the cultivated area of about 58 000 ha in the country (OMAF, 1990). The total number of date palm trees is in the range of 6 to 8 million trees of various varieties. Dates are produced for both local consumption and export. Annual production is estimated at 160 000 t. Forty percent is consumed by growers and owners, 25% is consumed by livestock and up to 35% is sold in domestic markets and exported (OMI, 1994). Dates contribute 12.5% of food energy consumption, this being the third most significant contribution after wheat and rice in the Sultanate (OMAF 1989a).

Dates are locally consumed in fresh or preserved form. Dates for export are factory-packaged. Various post-harvest unit operations are carried out on dates to preserve them for consumption, marketing, packaging or storage. The most prominent operations at the producer level by farmers and growers producing dates for farm families, is open-air sun-drying. At the factory level, two date packaging factories carry out unit operations with machines installed in the mid-1970s.

The present study aimed at investigating the status of the operations and technologies utilized, as part of a project on developing innovative post-harvest technologies, for preserving dates in the tropics, in general, and in Oman, in particular. Information and data relating to the status of the operations and equipment are presented and solar post-harvest technologies suitable for application are outlined. Statistical data and information gathered by the author through interviews with date growers with the use of structured questionnaires, personal communications and literature review are presented in this paper.

Post-harvest Operations by Farmers

Over 120 varieties of dates with local names exist in Oman (OMAF, 1991). The most common varieties are Fardh, Hillali, Khalas, Khusab, Khuneezi, Mabsli and Naghal. Date growing takes place mainly in Batinah (northern coast) and the Interior (Central Oman). The productivity of dates is estimated at 2 t/ha per harvest period, for the Batinah region and 4 t/ha for the Interior by Arthur D. Little in the Crop Enterprise Budget, 1982 (OMAF, 1989a). A farmer with 2 ha under fully bearing dates may, therefore, produce 4 to 8 t per harvest. Two to three ha of dates are indicated as average farm size by the Ministry of Agriculture and Fisheries. Some farmers reported that their date crop yielded an average of 5 tonnes are in a harvest period.

The bulk of date fruits are harvested from May through September. Some early bearing dates are harvested as early as April and late bearing ones are harvested in October. The peak harvesting period is July and August. Harvesting lasts over a period of three to four months for various varieties. Dates are harvested at three stages as follows: 1) ''bisr'' stage when the date is mature but not ripe; 2) ''rutab'' when date is partly ripe; and 3) ''tamir'' stage when the date is completely ripe. The moisture content of mature dates at harvest ranges from 34% to 72% wet basis with the average being around 50% wet basis. After harvest, dates are prepared for consumption, feed, market or storage. Dates for the market may be sold at the local market, to the Public Authority for Marketing Agricultural Produce (PAMAP) or to the Date Processing Factory.

During the preparation of dates for variuos purposes, post-harvest unit operations are undertaken by the producers. These include carrying harvested dates for washing or cleaning, ripening of the ''bisr'' or ''rutab'' stage dates, boiling of bisr of some varieties, sun-drying, sorting, packaging and storage (**Fig. 1**). The most common operation carried out at the producer level is open-air, sun-drying. Boiling or heat treatment is another major processing for the ''mabsli'' date variety.

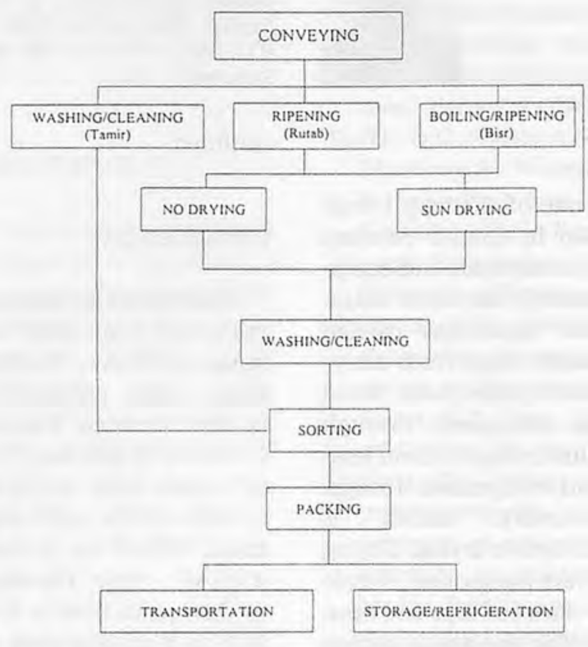

Fig. 1 Flow chart for processing harvested dates at farm level.

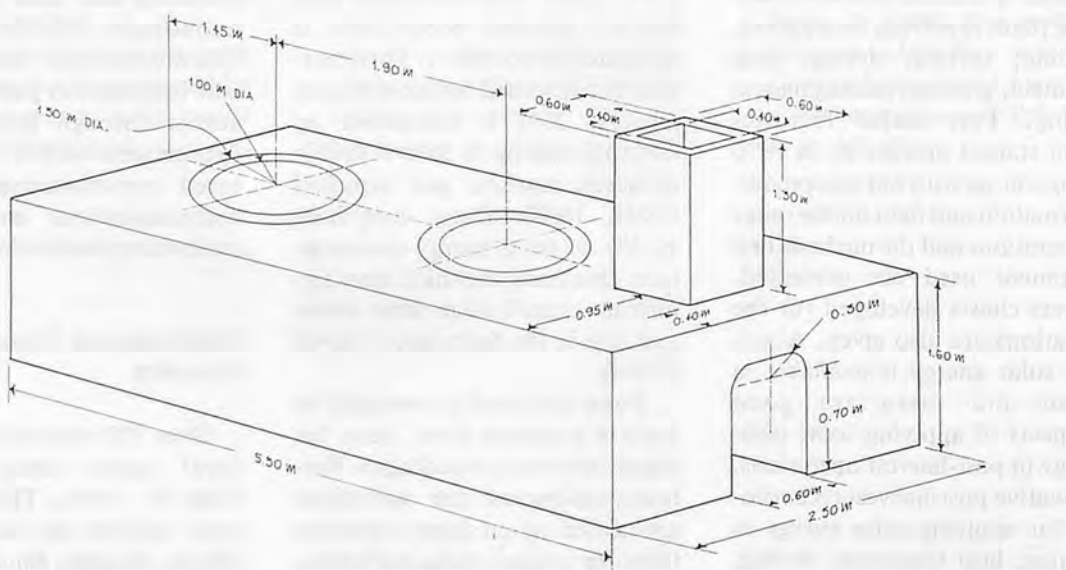

Fig. 2 Diagram of earth oven.

Fig. 3 Date drying in open containers.

Table 1. Equipment Used for Producer Level Operations

Operation	Equipment
Conveying	"Qafeer" (carrying container), plastic container, cardboard boxes, metal pans
Washing/cleaning	Washing basins
Ripening	Continues during sun-drying or storage
Boiling	Heat treatment for cooking "Mabsli" variety Earth oven is used
Sun-drying	Drying structures, including ground floor, platform, flat rooftop, open containers
Sorting	Manual
Packaging	Plastic bags and containers, ceramic containers, "khars" (Semi-airtight containers), wooden containers
Transportation	Cars, trucks
Storage	Room temperature storage, refrigerated storage

Heat Treatment

The "mabsli" variety is harvested at maturity before it ripens. It is heat-treated by boiling before it is dried. The cooking of "mabsli" gives it a good taste.

The fruits of mature dates are separated from the stalk after harvest. The fruits are placed in earthenware or metal vessels which contain water. The containers are placed on earth oven built in a cooking place called "Torukba". The oven dimensions average 5.5 × 2.5 m with an average height of 1.6 m (**Fig. 2**). The chimney of the oven is 1.3 m high. The oven is heated with dried date leaves or stalks.

Sun-drying

Farmers in Oman sun-dry their dates on flat surfaces on in open containers. The drying surface may be a ground floor, platform or roof-top. A ground floor used for drying may be located on or near a farm, in a village or town open space, at the courtyard of a house or on a hill- or mountainside which faces the sun. The floor may be covered with mats made from strands or with tents. Mats or tents are also used for covering the dates after drying.

The standard date drying platform is a raised surface locally referred to as "Al Daan". The platform is constructed from wooden, concrete or metal supports, wooden beams and mats made from date palm fronds. The platform surface is about 1 m from the ground and has an average dimension of 3 m by 4 m. The roof of most houses in Oman are built flat. The roof-tops, therefore, serve as suitable drying floors for dates.

Wooden, plastic or metal trays filled with dates are normally placed in courtyard of houses for the dates to dry (**Fig. 3**). The container in the foreground of the figure is locally called "Qafeer". It is made from date palm tree leaves and is normally used for carrying loads of 20 kg dates.

Open-air sun-drying of dates in Oman takes 14 to 21 days depending on the variety and weather conditions. Some date varieties such as "fardh" are allowed to dry on the tree since they do not fall when ripe. They are harvested dry, that is, at a moisture content of approximately 12%, wet basis, and hardly sun-dried further. Most date varieties are harvested for drying or storage at the "rutab" and "tamir" stages. Ripening continues during sun-drying or storage.

Producer Level Equipment

Besides the "qafeer" (carrying container) producers use plastic containers, cardboard boxes and metal pans for conveying dates. Containers which are used for boiling or cooking the dates are used as wash basins. During packaging, dates are placed in plastic bags and containers, ceramics or wooden containers and earthenware (semi-airtight) containers known as "khars". Transportation is carried out in cars and trucks. Storage is done in packages at room temperature or in refrigerated units when the farmer or farm family has such facilities. **Table 1** gives a summary of the equipment used for the various operations performed.

Post-harvest Operations at the Factory Level

Two public (governmental) date packaging factories which are to be privatized (OMI, 1994) exist in Oman. These are the Nizwa and Rustaq date factories located in the date producing areas. In the private sector, date packaging factories are being established. Examples is the Dateflakes factory in Rusayl, scheduled to start operation in March 1996. (The data presented here were obtained through personal communication and visits to the Nizwa and Rustaq factories in 1994 and 1995.)

Dates for packaging at the factories were obtained from farmers or growers working for farm families. Mature ripe dates are purchased at various centers in Oman. Dates are transported in special refrigerated vehicles to the factory. Plastic containers are used for holding the dates.

Factory Operations

Dates are handled on arrival at the factory with hydrualic lifts and are conveyed to the weighing area

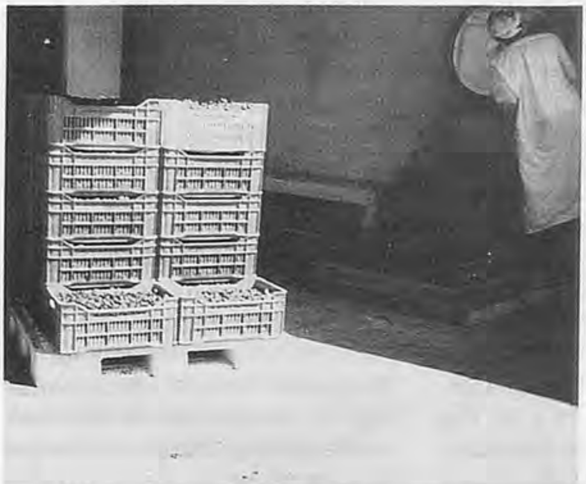

Fig. 4 Weighing of dates at the factory.

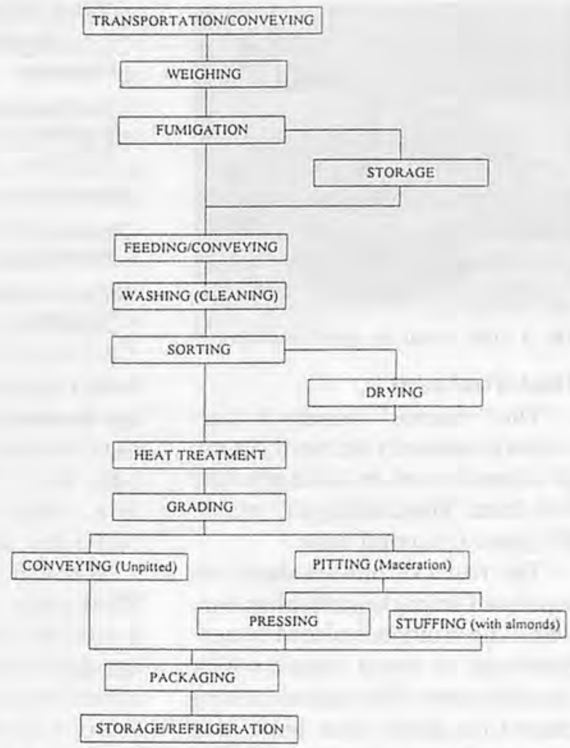

Fig. 5 Flow chart for date packaging at factory level unit operations.

of the factory building and weighed in the containers in which they have been sun-dried and transported (**Fig. 4**). The dates are fumigated with methyl bromide in a fumigation room to kill insects and other pests. Fumigated dates are placed in storage or sent for immediate packaging. The packaging process comprises unit operations involving feeding dates into a hopper and conveying them onto a conveying belt for cleaning with water from spray jets. Manual sorting of dates on the conveyor follows. Dates are then conveyed to a dry date hopper and the wet dates to a dryer. Dry dates are heat-treated on wooden trays in a heat treatment chamber. The treated dates are manually graded, packaged and moved into cold storage.

Dates are packaged in various forms. They may be packaged loose or pressed, pitted (macerated) or unpitted and pitted and stuffed with almonds. Pressing of dates is done by a pressing machine. Pitting and stuffing with almonds are manual.

Various packaged sizes are produced. Sizes range from 125 g to 22 kg. Packaging dates is both manual and mechanical. Packages consist of plastic bags and containers, cardboard boxes, date palm fronds baskets, bamboo and pottery containers. The sequence of unit operations at the factory is summarized in **Fig. 5**.

Factory Level Equipment

Both manual and mechanized operations are carried out at the factories. The pieces of equipment used are summarized in **Table 2**. The factories operate on electrical power with standby generators.

Factory Production

The Nizwa and Rustaq date processing factories were completed and started operating in November 1975. The packaging of dates started in the two factories in 1976 (OMAF, 1990). Raw date quantities purchased from farmers from 1976 to 1989 for packaging at the two factories amounted to 13 517 t. The two factories produced 11 352 t of packaged dates. Packaging takes place throughout the year.

Table 2. Equipment Used in Factory Level Unit Operations

Operation	Equipment
Transport	Refrigerated trucks Plastic Containers
Handling (conveying)	Hydraulic lift
Weighing	Weighing scale
Fumigation	Fumigation chamber
Feeding	Feeding hopper
Conveying	Conveyor belt
Cleaning/ hydration	Water spray jets
Sorting	Manual
Drying	Dryer
Heat treatment	Heat treatment chamber Steam boiler Wooden trays
Grading	Manual
Packaging	Manual Pressing machine Staplers Plastic bags and containers Cardboard boxes Date palm frond baskets
Storage	Refrigerated storage

Discussion

The open-air sun-drying carried out by farmers constitutes drying the dates under uncontrolled weather and environmental conditions. The disadvantages of open-air sun-drying are contamination with dirt, dust, rain, micro-organisms, attack and contamination by insects, birds and rodents and prolonged drying time. The contamination results in poor quality product and deterioration in storage leading to heavy post-harvest losses. Reliable estimates of losses are not available but post-harvest loss estimates obtained from date farmers range from 5% to 20%. Adoption of drying under controlled conditions should result in efficient drying and good quality products. No fumigation of harvested dates is carried out by farmers. The introduction of suitable form of fumigation to them is necessary.

Fumigation units and steam boilers were installed in the two factories in 1985 and operated in 1986 (OMAF, 1990), i.e., after 10 years of factory operation. The difference between the quantity of dates purchased from farmers and that packaged by the two factories from 1976 to 1989 constitutes 16% of the purchased quantity. This may reflect factory operational losses and may in part be due to the absence of fumigation units and steam boilers. The factories find the electric power which operates the machines to be costly. The factories have been operating for 20 years and require rehabilitation.

The process charts have been developed to indicate the sequence of the unit operations. They should be useful tools for process analysis of date post-harvest activities. Agronomic data obtained on the production level for dates harvesting period and moisture content at harvest should also be useful in developing a dryer for dates.

Solar energy is abundant in Oman. From solar energy information compiled by the Food and Agriculture Organization (1993), it is estimated that solar energy reaching the country is around 0.23×10^{-3} MJ.m^{-2}.s^{-1}. This figure is in the higher range of solar energy reaching the earth after depletion by hours of darkness, atmospheric absorption, cloudiness, etc. Summer climate in northern Oman is one of the hottest in the world and temperatures as high as 55°C have occurred (OMAF, 1989b). Summer months run from April through October. Dates are harvested during this period. Maximum average temperature during June is 40°C (OMAF, 1989b). Application of solar post-harvest technologies in date post-harvest operations have good prospects in Oman. Solar maturation chambers can be used for dates ripening, solar heating systems for heat treatment and fumigation, solar dryers for drying and solar assisted refrigeration system for cold storage.

Solar Ripening

To avoid unfavorable weather conditions and product contamination, mature dates may be harvested and ripened with solar heat. There are maturation chambers which are rooms or enclosed structures built to maintain uniform temperatures from 27 to 49°C and provided with humidity controls for artificial ripening (Nixon and Carpenter, 1978). Under the climatic conditions in Oman, solar maturation chambers can use solar heat for ripening dates.

Solar Heating

Solar cookers and water heaters are some of the most commonly developed devices that use solar energy. Reflector and box type cookers and solar water heaters operating on "thermosiphon effect" have been developed mainly for domestic use (Wieneke, 1980). Such solar heating systems can be applied to boil, cook or heat-treat dates.

Solar Drying

A wide variety of solar dryers have been developed for crop drying under controlled and protected conditions (Sodha et al., 1987). There are natural convection dryers that do not require any mechanical or electrical power to run a fan and forced convection dryers but which require the use of a fan or blower to pump air through the product. The natural or forced convection dryers can be direct mode where the product collects energy directly from the sun or indirect mode where the product is dried with warm air heated separately by solar collectors (air heaters). A mixed mode dryer is one in which the product is exposed to the sun and also receives heat from a stream of hot air. Examples of the solar dryer are shown in **Table 3**. A solar cabinet dryer can attain temperatures as high as 100°C for drying (Sodha et al., 1987). The examples of solar dryers listed in **Table 3** can be applied to solar drying of dates.

Solar Chamber Fumigation

Table 3. Major Classes and Examples of Solar Dryers

Category	Drying Mode	Components	Examples
Natural convection	Direct	Enclosure with transparent cover or side panels	Rack, solar cabinet dryer, glass roof dryer
	Indirect	Air heater (solar collector) and drying chamber	Chimney-type solar dryer, solar wind-ventilated dryer
Forced convection	Direct	Chamber with transparent cover and fan or blower	Down-draft dryer, tunnel solar dryer
	Indirect	Air heater, drying chamber and fan or blower	Shelf-type solar dryer, bin-type solar dryer

Dates which have not been fumigated with gaseous fumigants can be subjected to temperature of 66°C for half to one and half hours to destroy insects pests and their eggs (Nixon and Carpenter, 1978). Solar maturation chambers, cookers and dryers can, therefore, be adopted to perform the function of solar fumigation chambers.

Solar Assisted Refrigeration

Cooling, as for cold storage of perishable food products, represents one of the main energy requirements and accounts for use of large quantities of non-renewable fossil fuels. According to Singh, (1981) 3.4 times as much energy is used to store frozen food than to process it. The use of absorption refrigeration is a well established technology for space air-conditioning and other applications involving temperatures well above 5°C. A new solar-assisted absorption-cooling system which can achieve a cooling temperature of 0°C for freezing purposes has been proposed by Zuritz and Perez-Blanco (1993a and b). Freshly ripened dates that begin to show some deterioration after several weeks in a household refrigeration at about 4°C, have been kept for a year at −34°C with no apparent change in quality (Nixon and Carpenter, 1987). The solar assisted refrigeration unit proposed may be applicable to cold storage of dates.

Conclusions

Dates are produced in Oman for both local and overseas markets. Date farmers adopt various methods to preserve harvested dates. Post-harvest operations carried out by farmers range from carrying dates in traditional containers of 20-kg capacity and plastic containers to open-air sun-drying and room temperature storage. Two major processing factories established by the government in 1975 have been packaging dates for local consumption and export.

The operations carried out and technologies used by farmers and factories require the introduction of innovation and equipment rehabilitation. Since solar energy is abundant in Oman, solar post-harvest technologies involving use of solar energy for ripening, heat treatment, drying, fumigation and solar assisted refrigeration have been suggested for adoption.

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Ammonia as a CFC Alternative for Developing Countries: Its Problems and Solutions

by

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Abstract

The chloro fluoro carbon (CFC) ozone layer destruction oblige several countries to study alternative refrigerants. Many countries are considering discounting the production of R-22, even though it is not forbidden by the Montreal Protocol. The use of ammonia, particularly in domestic and commercial refrigeration application, represents one of the possible solutions to the CFC crisis. Several developed countries have been using ammonia which presents advantages such as its low cost and a tradition of more than one century utilization. However, ammonia has its opponents and supporters. Its misuse, particularly in developing countries, built up some skepticism. It is time to apply ammonia in its full potential.

The authors have analyzed some of the commonly encountered difficulties in ammonia installations which can be caused by high compressor discharge temperature reaching up to 150°C. Among the analyzed causes are the suction overheating, presence of scaling in jackets and condensers. Also, the authors suggest the operation of the system using saturated vapor at the suction, installations of liquid separation, and an adequate automatization. Water condensation is another problem of ammonia. The operation of ammonia systems with saturated vapor at the compressor suction enables discharge temperatures around 100°C in standard cycles ($T_{evaporation}$ (T_o) = −15°C and $T_{condensation}$ (T_k) = 30°C). These operating temperatures limit excessive compressor oil lost which causes refrigerant contamination and makes heat transfer more difficult in all heat exchangers. Also, according to the study, the ammonia systems may be employed in the compact version substituting the CFCs in all applications, although in air-conditioning indirect systems are recommended. Finally, the authors support increasing efforts on teaching the ammonia techniques to rescue a lost culture. In Cuba, the application of these measures allowed savings up to 15% in the electricity consumption and a substantial decrease in repair and maintenance costs.

Introduction

Ammonia is considered a very promising alternative refrigerant for CFCs substitution, particularly in some applications in commercial refrigeration. In developing countries, the advantages presented by R-12, R-22 and other working fluids inhibit the ammonia utilization in favor of using the technology developed for CFC refrigerants.

Ammonia, also called "the father of refrigerants" (Brossard Perez, 1970 and 1992), with excellent thermal properties that are ideal refrigerant for several applications, as in ice production and for large cold chambers. Ammonia has a greater refrigerant effect, per unit of mass, than any other refrigerant allowing the use of smaller systems.

Its toxicity is a great disadvantage having, however, a relatively high heat transfer coefficients. Today, ammonia utilization is restricted to large installations (Stoecker and Saiz Jabardo, 1994). However, the recent world events have blamed the CFCs for the ozone layer depletion which makes us to suggest that ammonia utilization be confined to small- and medium-sized refrigeration system.

Many authors, including Lorentz (1989), Saiz Jabardo (1993 and 1995) and Lindborg (1995), have called attention to safety measurements when using ammonia as refrigerant. Among their suggestions, they included the use of sensors to alert its presence in dangerous concentrations and the development of research to reduce the amount of ammonia in small- and medium-sized installations. In parallel to technical aspects, engineers should pay a great attention to legislation regarding ammonia use in developing countries. If laws are to be written without good technical guidance they may become more harmful than what they tried to prevent and control.

Special attention should be given to maitenance in developing countries where ammonium use is not priority. Lack of adequate and continuous maintenance may jeopardize safety and energy efficient systems. As an example, in Cuba, the application of these measures allowed savings up to 15% in electricity consumption and a substantial decrease in repair and maintenance costs (Brossard Perez and Guillén, 1992; Brossard Perez and Macias, 1992).

Commonly Encountered Deficiencies in Ammonia Systems

The most common deficiencies in ammonia systems are:

- large amount of energy utilized by poorly managed the systems;
- high condensing pressures;
- high consumption of oil refrigerants;
- excessive wearing of compressor parts;
- high cold chamber temperatures, exceeding the required range; and
- frequent refrigerant leaking.

These deficiencies have some relationship between each other as discussed below.

Table 1. Thermodynamic States (P, T) for R-12, R-22 and Ammonia at $T_o = -15°C$; $T_k = 40°C$; $\Delta T_s = 20°C$

State	R-12		R-22		ammonia	
	P(MPa)	T(°C)	P(MPa)	T(°C)	P(MPa)	T(°C)
1	0.19	−15	0.29	−15	0.24	−15
1′	0.19	5	0.29	5	0.24	5
2	0.98	70	1.6	86	1.56	147
3	0.98	40	1.6	40	1.56	40
3′	0.98	—	1.6	—	1.56	—
4′	0.19	−15	—	−15	0.24	−15

Distinct Features of Ammonia during Compression

To improve compression, we should perform an analysis of one-stage refrigeration cycle using R-12, R-22 and ammonia. Considering a standard cycle having $T_o = -15°C$ and $T_k = 40°C$ with suction superheating (before compression suction) $\Delta T_s = T_{chamber} - T_{1'} = 20°C$ for all cases.

According to the data presented in **Table 1**, ammonia temperature at the compressor discharge may reach up to 147°C. Since, the flash point temperature of the oil is around 150°C, the lubrication is deficient above 130°C.

The superheating technique is employed for R-12 to sub-cool liquid refrigerant leaving the condenser. Superheating is necessary because it increases the specific refrigeration capacity (q_o) and separates liquid refrigerant from oil because R-12 is highly miscible in oil. Superheating does not affect the refrigeration system performance when ΔT_s does not reach high values.

Ammonia suction superheating does not produce the same benefits as with R-12. For ammonia, superheating in some cases may cause explosions. Therefore, liquid (sub-cooling) - vapor (superheating) heat exchange cannot be used for ammonia, unless it is limited to a maximum of ΔT_s = 10°C and kept around 5°C. For ammonia the insulation is of great importance. Also, a high quality insulation should be cased. Insufficient or humid insulation may result in excessive superheating at the compressor suction.

Atmospheric air condensation is responsible for insulation humidification. This means that, the insulation should be thick enough so that external temperature is greater than the higher dew point temperature of the installation site. This concept is of a great importance in the use of ammonia.

Lubricant Oil and Its Problems in Ammonia Systems

The compressor discharge temperature sets the temperature of some other points of the cycle **(Fig. 1)**. Conducted studies have demonstrated that utilized refrigerant oils for ammonia have the characteristics presented at **Table 2**.

At the compressor crankcase and cooling jackets at high temperatures the oil evaporation provokes high oil vapor flow rates which cannot be eliminated by the oil separator and will finally go through the condenser where the oil vapor will condense creating a thin film that impairs heat trans-

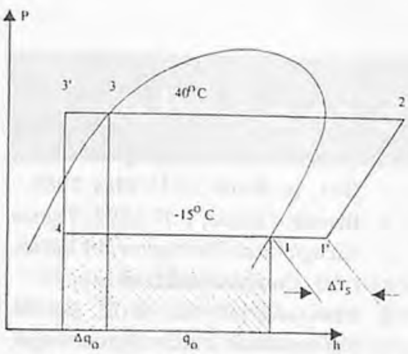
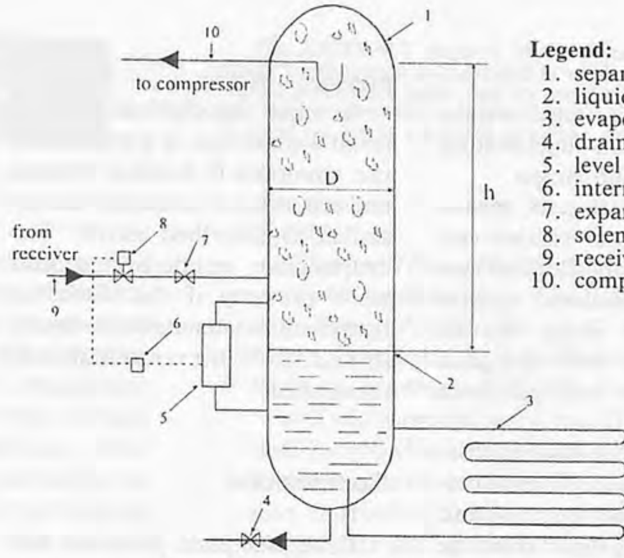


Fig. 1 Standard P-h diagram for stnadard conditions ($T_o = -15°C$; $T_k = 40°C$; $\Delta T_s = 20°C$).

Table 2. Refrigeration Oil Lost at Different Temperatures

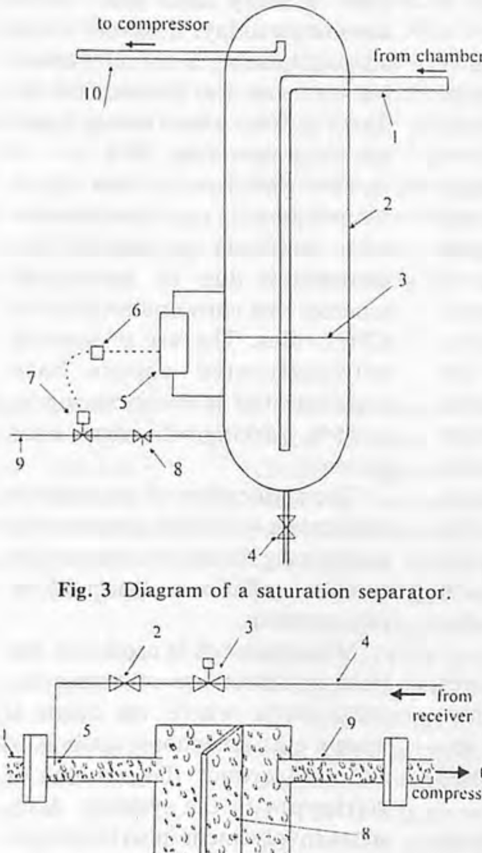
Oil Temperature (°C)	Oil Lost (%)
80	3
100	8
120	16
140	30

Source: Zukowski, 1995.



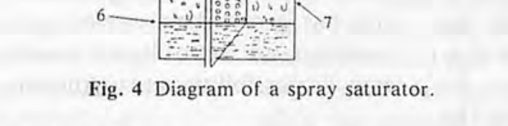
Legend:
1. separator
2. liquid level
3. evaporator
4. drain
5. level control
6. intermediate relay
7. expansion valve
8. solenoid valve
9. receiver line
10. compressor suction line

Fig. 2 Ammonia flooded system.



Legend:
1. suction line
2. saturation separator
3. liquid level
4. oil drain
5. level control
6. intermediate relays
7. solenoid valve
8. expansion valve
9. liquid tube from receiver
10. suction line from the compressors

Fig. 3 Diagram of a saturation separator.



Legend:
1. suction line
2. expansion valve
3. solenoid valve
4. liquid line from receiver
5. spray
6. level
7. separator
8. internal division
9. suction to compressors

Fig. 4 Diagram of a spray saturator.

fer. The increase in oil loss requires a larger condenser with a surface several times larger than the design surface. The usually considered design oil film thickness is 0.05 mm when the compressor discharge temperature is 120°C.

Another problem is the oil decomposition and the formation of uncondensable vapors implying higher condensing pressure and temperature. A particular problem occurs with ammonia evaporative condensers. The high operating temperatures at the compressor discharge will then affect its good operation.

Employed Systems and System to Be Used

To avoid liquid surge at the compressor in ammonia systems, a superheating technique similar to the CFCs systems is employed. For this purpose, it is recommended the utilization of thermostatic valves allowing superheating between 3 to 5°C be considered.

Each degree of temperature increase in condensation raises energy consumption of 2 to 2.5%. In addition, wearing results from poor lubrication may cause temperatures to go above 120°C, reducing the expected compressor life time.

The normal practice is to increase the compressor pump oil flow rate by increasing the pump discharge pressure. This will compensate poor lubrication but will increase the quality of oil at the condenser.

Therefore, it is important to observe a minimum superheating (Δt_s); and no liquid surges.

Minimum ΔT_s at zero, means that saturated vapor suction can be obtained by using flooded systems and well insulated suction line. The liquid surge can be minimized with well designed liquid separators and adequate automatization.

The diameter (D) of separators (**Fig. 2**), should allow low velocity (between 0.3 and 0.5 m/s) and a vapor "residence time" from the liquid level to the suction (h) should be between 2 and 5 seconds.

The use of a saturation separator or spray saturator will ensure proper saturation in existing systems (**Figs.** 3 and 4).

The saturation separator illustrated in **Fig.** 3 is actually more than a separator where the vapor admitted by the compressor is washed and saturated. Its dimensions are the same as a liquid separator. This liquid level from the receiver ensures that vapor saturation is suctioned off. On the other hand, the spray-saturator shown in **Fig.** 4 also ensures that saturated vapor is suctioned off. To avoid liquid surges one may use a small leveled separator which shows the manual expansion valve set point.

Still the third method requires the use of a commercial thermostatic valve that likewise ensures that saturation is suctioned off.

Before any of the above three ways of separating saturation, it should be emphasized that the operating system generates a high superheating temperature. As such, it very important that the ΔT_s be reduced to below 10°C. Otherwise, the energy indexes are jeopardized by a reduction in compressor capacities.

In small installations such as small warehouses, it is possible to use ammonia if flooded systems and evaporative condensers are installed as described earlier. The evaporative condenser should work properly if the discharge temperature is maintained between 95 and 105°C for reasons already mentioned.

Conclusions

Using adequate pressures and safety practices, ammonia may be used in many cases where CFC dominates today. Its direct use in air conditioning is not only possible but it can also be used with indirect systems where energy losses are no greater than 20%.

The deficiencies that in a majority of the cases are presented in ammonia systems are fundamentally due to inadequate schemes that copy and employ the CFCs rules. The use of systems with saturated vapors have demonstrated an energy saving up to 15% working with compressor systems.

The application of evaporative condensers with these systems may render easy the use of ammonia in small installations, especially in refrigeration.

More research is needed in the field of direct use of ammonia, particularly where no harm is sought e.g., greenhouse cooling, in order to reduce the amount of refrigerant in the systems. Also, more involvement in writing legislation is needed. Although ammonia has more than one-century tradition, the fear of its use reveals how its possibilities are unknown.

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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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Performance Indices of Manually-operated Maize Shellers: Singh, Ram Dhiraj, Scientist, Agril. Engg. Div., Indian Institute of Sugarcane Research, Lucknow, India; and R.B. Ram, Professor and Head (Farm Machinery); Nageswar Prasad, Graduate Student, respectively, College of Agril. Engg. R.A.U. Pusa, Samastipur, India.

In India maize shelling is done traditionally, by spreading the maize cobs on the floor and beating by stick. In the process, the farmers have to bend a number of times. In order to reduce the drudgery and improve capacity, hand-operated maize shellers were developed. The paper deals with the performance evaluation, energy requirement, performance index and cost of operation of different maize shellers. The effect of operator's pulse rate on the capacity during the operation was also studied. The capacity of the sheller ranges from 11.78 to 28.35 kg/h with the energy requirement of the 4.60 to 16.46 MJ/q grain. The cost of operation ranges from 15.56 to 38.29 Rs/q.

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Duration of Work of Draft Animals During Tillage Operations in Adamawa State of Nigeria: Umar, Bobboi, Institut fuer Land-, Umwelt- und Energietechnik, Universitaet fuer Bodenkultur, Nussdorfer Lande 29-31, A-1190, Vienna, Austria; and M.A. Haque, Department of Agricultural Engineering, University of Maiduguri, Maiduguri, Nigeria.

A study was conducted in 13 of the 16 local government areas of Adamawa state in Nigeria for the duration of work of draft animals during tillage operations. Two groups of animals were identified: those working in the morning only and those working both in the morning as well as in the afternoon.

Of the 104 animals considered, 21.15% belonged to the first group while 78.85% belonged to the second group. The average duration of work of the first and second groups of animals was 4.5 and 5.4 hours per day, respectively, while the overall average duration of work was 5.25 hours per day when both groups were put together. It was observed that there is still some scope to increase the duration of work of draft animals in tillage operations.

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Effect of Tillage Practices on Energy Use Pattern of Clusterbean — Pearl Millet Rotation in Arid Zone: Patidar, M.; A.K. Singh; and H.P. Singh, respectively, Central Arid Zone Research Institute, Jodhpur 342003, India.

A study was conducted on different tillage practices for growing cluster-bean-pearl millet rotation in sandy soils of arid zone. The results indicate that disc harrowing (cross) consumed more energy (12 715 MJ ha^{-1}) and plough plant system consumed less energy (10 477 MJ ha^{-1}). The treatment cultivator (one run) gave the highest output-input ratio of 13.0 followed by disc harrowing (one run) 12.8 output-input ratio. The specific energy was lowest with disc harrowing (one run) 4.9 MJ kg^{-1} grain followed by cultivator one run (5.0 MJ kg^{-1} grain). This shows that the minimum tillage practices, namely; cultivator (one run) and disc harrowing (one run) are more energy efficient as compared to either plough plant system or disc harrowing (cross) in sandy soils in the arid zone.

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Differences in Terminal Velocity Distribution: Good Enough for Cleaning Bean Seeds and Grains: Aguirre, Roberto, Associate Professor, National University, A.A. 237, Palmira, Colombia, South America; and Adriel E. Garay, Seed Consultant, 6835 SW Raleighwood Way, Portland, OR 97225, USA.

The terminal velocity (TV) distribution of inert matter and pure grain particles from seed samples of bean cultivar PVA 773, threshed with three different methods: rotary thresher, beating on the floor and beating on a suspended wire screen, were determined using a laboratory South Dakota blower. The results show that a high percentage of the inert matter present on the three samples have a lower TV than pure grain, making it possible to clean the lots using an air current with an average velocity of 16.0 $m.s^{-1}$. The differences in TV distribution of inert matter and pure grain on the lots allow the removal of contaminants increasing the average physical purity of the samples from 88.1% up to 99.3%. For the three samples, the pure grain with the lowest TV shows poor appearance so air can also be used to upgrade bean seed lots. The results show that an air current is good enough for cleaning and upgrading bean seed lots threshed with any of the mentioned traditional methods.

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A New Approach to Model Flooding in East-Bangkok: Sangchan, S., Head of the Department of Agricultural Engineering, Faculty of Engineering; P. Mekpruksawong, Staff member, Department of Agricultural Engineering, Faculty of Engineering; and S.S. Makhanov, Professor, Faculty of Information Technology, respectively, King Mongkut's Institute of Technology Ladkrabang, Bangkok 10520, Thailand.

We propose a new computer model of flood developed for water systems comprising large canal networks. The model is oriented to assist a decision-making in farming.

Our approach is based on the diffusion wave equation and related to a modified version of the so-called "calculations with apparent cross-sectional flow areas". The solution procedure of the resulting finite difference equations requires a generalization of the stable numerical algorithm as applied to the case of combined river-surface flows.

We simulate the flood evolution in the lower Chao-Praya river basin located in the Eastern areas of Bangkok. The region represents an important area for agriculture and farming in Thailand.

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A New Design of Diesel Engine Swirl Chamber: Tian, Dongbo, Ph.D. Student; Detao Li, Professor, respectively, Dept. of Power Engineering, Jiangsu University of Science and Technology, Zhenjiang, Jiangsu, P.R. of China; and Nobutaka Ito, Professor; Koji Kito, Assoc. Professor; and Xiulun Wang, Assoc. Professor, respectively, Laboratory of Power and Energy, Dept. of Bioproduction and Machinery, Faculty of Bioresources, Mie University, 1515 Kamihama, Tsu-shi, Mie-ken, 514 Japan.

A new configuration of swirl chamber was developed to improve the performance of diesel engine based on the fundamental research on the swirl chamber of diesel engine. The results of experiments show that the new design of swirl chamber improved the fuel economy of diesel engine, especially under partially loaded operation. When the engine (S195) was operated at the rated running condition (8.82 kW/2 000 rpm), the specific fuel consumption of the new chamber was a bit lower than that of the original chamber. When the engine was run at 4.41 kW/2 000 rpm, the specific fuel consumption of the new chamber was 18 g/kW-h lesser than that of the original swirl chamber. The combustion characteristics of the new combustion chamber were analyzed by means of the rate of heat release (ROHR). The cold-startability of new swirl chamber was also improved. ■■

FINDER SYSTEM FOR AMA ARTICLES AVAILABLE

A computerized finder system consisting of a database listing of all technical articles in Agricultural Mechanization in Asia, Africa and Latin America since it began publication in 1971, along with searching software, is available without charge. The system is on a 3 1/2 inch diskette for use with IBM-compatible computers. Requests for this diskette should be sent to:

William Chancellor
Bio/Agric. Engineering Dept.
University of California
Davis, CA 95616, USA
(e-mail: wjchancellor@ucdavis.edu)
(fax: 916-752-2640)

The diskette will be sent by air-mail. Those with access to the INTERNET may download AMA-96.EXE (or a larger agricultural engineering database, AE-NDX95.EXE) by using File Transfer Protocol (FTP) from POPPY.ENGR.UCDAVIS.EDU (or 128.120.65.75 for those wishing to use numeric characters), User = anonymous, Password = guest. Before "getting" either file by FTP, first type: binary <enter>. Either of the above files should then be placed by itself in a hard-disk subdirectory. Typing the file name (without extension) <enter> will result in a ready-to-run system activated by typing: HI <enter>.

First Regional Latin-America Conference on Techniques and Equipment for Field Experiments

November 23-26, 1998
Instituto Ingenieria Rural, Argentina

Organize the First Regional Latin-American Conference on Techniques and Equipment for Field Experiments — IAMFE ARGENTINA 98 with the purpose of interchanging experiences, scientific and technical knowledge with relation to the practical execution of field experiments and laboratory activities; as well as instruments and equipment for that purposes.

This meeting aims to satisfy requirements from Research and Development Centers; Universities; Plant Breeders; Tractor, Farm Machienry and Equipment Manufacturers, as well as others interested Sectors.

Subject Area

- methodology and implementation of field experiments
- machinery and equipment for field experiments:
  - machines and equipment for soil analysis.
  - machines and equipment for drilling and planting crops
  - fertilizer distributors, sprayers and equipment for the maintenance of crops
  - grain and forage harvesting equipment.
- development of instruments and equipment for field and laboratory
- standards and certification of agreements on machinery and specific equipment
- seed production and processing
- electronic and automatic equipment and procedures
- irrigation, drainage and management of climatic information
- safety, ergonomics and contamination control
- world agricultural research

Presentation of Paper

Until May 31st, 1998, original papers will be received, which may be included in the following areas:

- *Scientific-Technology Research*. This shall include the following: 1. Summary in Spanish; 2. Summary in English; 3. Introduction and Past History; 4. Materials and Methods; 5. Results and Discussion; 6. Conclusions; 7. Bibliography quoted. Maximum six pages
- *Communications*: Developments in Research Projects, methodology novelties and other contributions of general interest. Maximum four pages.

Conference Location

Instituto de Ingeniería Rural
C.C. 25 (1712) - Castelar / Buenos Aires, Argentina
Telefax (54-1) 665-0495 / 0450
e-mail: ingrura@inta.gov.ar
Secretaría: Ing. Lidia D. de Cobo / Lic. Adriana Fuica

Agricultural Engineering Workshop 1998

December 10-11, 1998
Hanoi, Vietnam

The workshop on Agricultural Mechanziation — Current Situation and Issues of Priorities will be held December 10-11, 1998 in Hanoi, Vietnam. The workshop is co-organized by Vietnam Institute of Agricultural Engineering (VIAE) and Vietnam Society of Agricultural Machinery

Objective of the Workshop

- To exchange experience in the application of appropriate technologies and machinery for agriculture under tropical agricultural condition.
- To establish the relationship for the cooperation among scientists, engineers, specialized Societies/Association, Institutes and Universities aiming to promote the development in the areas of Agricultural Mechanization and Rural industries.

Registration Procedures

Registration form for the Workshop should be completed and sent to:
Prof. Dr. Pham Van Lang, Director
Vietnam Institute of Agricultural Engineering (VIAE)
A2-Phuong Mai - Dong Da - Hanoi - Vietnam
Return of Registration form: before 31 August 1998.
Receipt of the Papers for presentation: before 30 October, 1998. VIAE will send invitation letters to the representatives who have registered to participate in the Workshop to expedite the procedures for passport and entry visa.

Agriculture Asia '99 and Postharvest Horticulture Asia '99

May 13-16, 1999
World Trade Center Metro Manila, Metro Manila, Philippines

In 1997, the second staging was participated by 117 companies from 15 countries/areas with a strong presence from the local and overseas participants. There were three national pavilions from Italy, UK and USA. The four-day show attracted 5 408 trade visitors and featured the latest technologies and equipment on postharvest horticulture, irrigation, agri-industry, fisheries and aquatic resources, animal production and health, and other related sectors.

In 1999, Agriculture Asia '99 and Postharvest Horticulture Asia '99 is expected to draw an even bigger crowd as the relevance and magnitude of this event becomes known in and around the Asia Pacific region. In addition to Agriculture Asia '99 and Postharvest Horticulture Asia '99, a simultaneous exhibition specifically focused on agricultural machinery and equipment will take place. Agricultural Machinery Manufacturers Asia '99 will highlight the most advanced machinery and tools to maximize agricultural output. A definite must-participate-in show!

Conference Call for Papers

Numerous issues and concerns need to be addressed to enable agriculture to grow at a steady pace. Some of these include the provision and maintenance of rural infrastructure (irrigation, drainage, farm-to-market passages), acquiring advanced technologies, farmer's access to rural credit, price stability, enhancing export and liberalizing strategic industries. As such, a conference will takes place in conjunction with the Agriculture Asia '99 and Postharvest Horticulture Asia '99 exhibitions. Interested speakers to this one-of-a-kind conference are requested to submit their abstract of 250-500 words (in English) to the organizer by September 30, 1998.

Should you require further information, please feel free to contact us through the address below or by fax through number (632) 815-3152.

HQ Link Philippines, Inc., Unit B, 8th Floor, Cacho-Gonzalez Building, 101 Aguirre Street, Legaspi Village, Makati, Metro Manila, Philippines Tel: (632) 810-3694, 810-5685.

First International Forestry Engineering Coñference

June 28-30, 1999
Edinburgh, Scotland

The Conference will be held in Edinburgh between 28th-30th, June 1999. The theme is "Forestry Engineering for Tomorrow".

This Call for Papers seeks a wide range of material. The papers will, however, focus on developments in engineering which represent the advancement of the forest industry. We would like to cover all that is new, especially in the major forestry countries. Much of the engineering content will be in harvesting, but we aim to encourage papers in roading, bridging, water, wood residues, engineered timber, timber structures, pollution, safety, computing, GIS, pulping, sawmilling and much more...

The core of interest will lie in the diversity of harvesting techniques and the engineering involved. This is particularly appropriate as it is the fastest developing sector of engineering today. Only 15 years ago most harvesting was done by skidders and chain saws. Today we have sophisticated purpose-built hydraulic masterpieces with computer brains. We look forward to receiving contributions on the latest harvesters, forwarders, bailers, chippers, etc. Who knows what the next 20 yaers will bring and it is conferences like this that will help to sustain the momentum by creating a forum for exchanging ideas.

Contact:
Geoff Freedman
Conference Convener
email: geoff.freedman@forestry.gov.uk Tel: 01721 720 448 Fax: 01721 723 041
Forestry Engineering, Greenside, Peebles, Scotland, EH45 8JA

13th International Conference of the ISTVS

September 14-17, 1999
Munich, Germany

The 13th International Conference of the International Society for Terrain-Vehicle Systems (ISTVS) will be held in the buildings of the Technische Universität München in Munich from 14 through 17 September 1999.

As we are at the verge of the 21st century, this conference - in accord with the commitment of the President of the Society - provides a forum for young people to exchange their experience and ideas with the traditional membership and guests to stimulate discussions and also to promote advancement on all aspects of design, development, research and operations of vehicles and machinery for agriculture, earthmoving, construction, forestry, transportation and military fields.

Further information will be provided with the Third An-nouncement published in January 1999.

For the latest information visit the conference Web site: http://www.lrz-muenchen.de/~ISTVS/munich99.htm

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TAE '99 — International Conference

September 15-17, 1999
Prague, Czech Republic

Aims and scope of the conference

The scope of the conference is to give the state of the art presentations on the latest topics in Agricultural Engineering in scientific sessions, posters, videos, and meetings of special interest groups.

The main topics

- Theoretical base of agricultural engineering
- Technique in plant production
- Buildings and technique in animal production and processing industry
- Energy and mobile transport means
- Quality, reliability and maintenance of machines
- Electronics and automation

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The Essential Electronic Agricultural Library: A Compact Disk Library for Developing Countries to be produced by Cornell University with support from the Rockefeller Foundation

Cornell University's Albert R. Mann Library and the Rockefeller Foundation have initiated a partnership which will result in an historic and groundbreaking information product: The Essential Electronic Agricultural Library, or TEEAL. This electronic library contains the full text — complete with all graphics and illustrations — of 125 agricultural journals, stored on compact disk. Designed to support agricultural research in regions where there is an urgent need for increased food production, TEEAL will be made available to 113 of the lowest income food deficit countries (as listed in the World Bank's 1996 *World Development Report*). Comprehensive scientific libraries are not common in these countries. By providing information to support agricultural education and research, TEEAL will aid in increasing food production. Dr. Robert Herdt, Senior Agricultural Officer at the Rockefeller Foundation, believes that "this project has the ability to change the quality of research and instruction in developing countries more than almost any other project."

The journals in TEEAL are those which are of most fundamental importance to developing countries, titles first selected by citation analysis and then reviewed by scholars from all over the world. Issues published from 1993 to 1996 will be scanned (photographed into a computerized format). The resulting digital page images will be stored on compact disk, a durable easy-to-use medium which can be used with standard microcomputers. The product will not require telecommunications or Internet access.

John Woolston of the International Maize and Wheat Improvement Center in Mexico is only one of many who are excited by the impending appearance of TEEAL. He says that TEEAL "represents appropriate technology for developing countries. Where it's impossible to keep a printed library free of dust, heat, and humidity a compact disk installation can be kept secure. And once the system is installed and learned, the cost of the copies is nigh infinitesimal!"

TEEAL can be distributed at low cost, to developing countries only, because 40 of the most prestigious scientific publishers in the world have granted copyright permission for their journals to be included. This digital library is made possible by the generous cooperation of publishers such as Academic Press, the American Society for Agronomy, Bangladesh Agricultural University, Elsevier Science, the Food and Agricultural Organization (FAO), the Instituto Agronômico (Brazil), the South African Society of Animal Science, and the National Research Council of Canada. Representative titles include *Agronomie, Aquacultural Engineering, Australian Forestry, Developing Economies (Japan), Food Policy, Journal of Environmental Quality, Journal of Genetics and Breeding, Netherlands Journal of Agricultural Sciences, Tropical Grasslands, and World's Poultry Science Review*. Societies and associations provide 40% of the titles while 49% are from commercial publishers and corporations.

Powerful search-and-retrieval software will make it easy for students and researchers to find and read complete articles about soils, weather, crops, food processing, nutrition, animal and veterinary sciences, environmental protection, and allied topics. A TEEAL user sitting at a microcomputer will use a computerized index to locate a journal issue (such as the March 1996 issue of the *Journal of Hydrology*), information on a specific subject (such as mycorrhiza), or articles by an author. The TEEAL system will present brief information on the screen, enough to lead the investigator to the compact disk containing an article of interest. The disk will then be inserted into the computer's compact disk drive so that the article can be read from the screen or printed on a local printer.

Scanning of the estimated 675 000 pages in TEEAL will begin early in 1998. The product, packaged in 70 compact disks with complete instructions for installation and use, will be available at the end of the year. An annual update to TEEAL will appear 9-12 months after each year's final issues have been printed. Annual updates will be issued for ten years after which information access via the Internet is expected to be widely available in developing countries. The library is the ultimate aim of eight years' effort by Mann Library and Dr. Herdt. Production of TEEAL will be funded by a grant of $965 000 and sales of sets to developing countries. 150 institutions have already indicated their interest in purchasing sets, which will be 10% of the normal cost of subscribing to all the journals in the set. The cost of the basic set for 1993-1996 will be $10 000, with annual updates priced separately. TEEAL will not be available to industrialized nations.

For more information about TEEAL; contact Mr. Olsen at (607) 255-8939 or at WCO1 @cornell.edu.

NEWS

The Mendel Univ. of Agriculture and Forestry, Czech Republic has Awarded Prof. Egil Øyjord

The Mendel University of Agriculture and Forestry in Brno, Czech Republic, has awarded Professor Egil Øyjord, Founder and President of IAMFE, a medal and a diploma for his world-wide contribution to mechanization of field experiments and in particular for his co-operation with the Czech plant breeders.

The ceremony took place at the opening of The 3rd Conference of Czech Plant Breeders and Research Workers in the Mendel University of Agriculture and Forestry, Brno, on February 3rd, 1998.

Prof. Egil Øyjord has earlier received the Gregor Mendel Commemorative medal (1980) and the Mexican issued Green Revolution Commemorative medal (1972).

At the banquet for celebration of the 30th anniversary of IAMFE and closing of the Ninth International Conference and Exhibition on Mechanization of Field Experiments in Beijing on October 19, 1994, Prof. Øyjord was awarded a plaquet of gratitude for his outstanding contributions to international agricultural research and most gratefully from China.

In 1994 Prof. Øyjord was appointed Honorary Professor of Beijing Agricultural Engineering University (now China Agricultural University).

Professor Øyjord started his research work on mechanization of field experiments in 1955 and The International Association on Mechanization of Field Experiments (IAMFE) in 1964.

The Øyjord plot seeders for plant breeding are in use in more than 100 countries. ■■

Power Tiller Research and Industry in India

(India)

by A.C. Varshney, Suresh Narang and A. Alam

The book entitled 'Power Tiller Research and Industry in India' Contains information related to scope of power tiller in India, construction of power tiller (engine, power transmission, clutch, brake, steering system, control mechanism, chassis, frame and, wheels), power outlets, balancing and rotary tiller. The chapter on research and developments includes techno-economic survey, evaluation of power tiller and matching equipment, application of power tiller in agro forestry, ergonomics of power tiller operation, traction devices and details of matching equipment developed in India. One chapter on power tiller in India has also been included in the book. The publication will be useful to the farmers, manufacturers and research and extension workers to acquaint about the latest development in equipment and technologies related to power tiller. The book may also be useful to the planners and policy makers for taking policy decisions regarding the power tiller technology. Page 161, Price US Dollar: 25.

Contact: Director, Central Institute of Agricultural Engineering, Nabibagh, Berasira Road, Bhopal - 462 038 (M.P.) India.

Renewable Energy Applications to Industries

(India)

Editors: C. Palaniappan, Ajit Kumar Kolar and T.M. Haridasan

Over the last decade, industries all over the world, particularly in the third world, are showing enhanced interest in energy conservation measures as also in the acceptance of renewable energy alternatives wherever possible. In this context the Planters Energy Network (PEN), Madurai Kamaraj University (MKU), and Indian Institute of Technology Madras (IITM) pondered over the idea of jointly organizing an International Workshop to bring together experts from academia, R and D institutions, industries, and national and international agencies to share their experiences in the areas of Energy Conservation and Renewable Energy for mutual benefit. This resulted in the organization of the Second International workshop at IIT Madras during April 9-11, 1997.

After a plenary session on the main areas of thrust, the workshop offered scope for indepth discussions in technical sessions dedicated to technology aspects of energy conservation, solar photovoltaics, solar thermal systems, biomass based technologies, cogeneration, energy management aspects, and economic considerations including financial issues with soft loan and other incentives. There were panel discussions as well resulting in the emergence of certain recommendations for early realization of the objectives.

273 pages, 18 × 24 cm, hardbound

Published by N.K. Mehra for Narosa Publishing House, 6 Community Centre, Panchsheel Park, New Delhi 110 017 and printed at Rajkamal Electric Press, Delhi 110 033 (India).

A Report — Second International Workshop on REAPOI

(India)

The report of the workshop on renewable energy applications to plantation and other industries (REAPOI), held 9-11 April, 1997 at IIT Madras, Chennai, India. The workshop was co-organized by Planters Energy Network (PEN), Madurai Kamaraj University (MKU) and Indian Institute of Technology Madras (IITM).

Principles of Process Engineering — Fourth Edition

(USA)

by S.M. Henderson, Prof. of Univ. of California; R.L. Perry, Prof. of Univ. of California; and J.H. Young, Prof. of North Carolina State Univ.

This fourth edition of *Principles of Process Engineering* provides expanded coverage on the basic transport phenomena of fluid flow, heat transfer, and mass transfer.

While this revision retains an agricultural flavor, an increased emphasis is placed on more general processing applications. The primary emphasis is given toward those basic relationships which may be applied to a multitude of problem areas.

Other major improvements in this edition include a conversion to SI (System International) units throughout and the use of computer software packages for problem solution.

This textbook demonstrates the importance of process engineering. Discover how process engineering provides the basics for many engineering problems.

353 pages, 6 × 9-inches, softbound, US$49.50 List; US$39.50 ASAE Member.

NEW PROCEEDINGS Published by The American Society of Agricultural Engineers as follow:

Livestock Environment — Proceedings of the Fifth International Conference, May 1997, Bloomington, Minesota;

Dairy Housing Conference — Proceedings of the Fourth International Dairy Housing Conference, January 1998, St. Louis, Missouri;

Drainage in the 21st Century: Food Production and the Environment — Proceedings of the 7th Annual Drainage Symposium, March 1998, Orlando, Florida; and

On-Site Wastewater Treatment, Vol. 8 — Proceedings of the Eight National Symposium on Individual and Small Community Sewage Systems, March 1998, Orland, Florida.

Mail to: ASAE, 2950 Niles Road, St. Joseph, MI 49085-9659 USA. (Voice: 616-429-0300, Fax: 616-429-3852).

Computer Simulation Analysis of Biological and Agricultural Systems

(USA)

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by Barney K. Huang

Computer Simulation Analysis of Biological and Agricultural Systems focuses on the integration of mathematical models and the dynamic simulation essential to system analysis, design, and synthesis. The book emphasizes the quantitative dynamic relationships between elements and system responses. Problems of various degrees of difficulty and complexity are discussed to illustrate methods of computer-aided design and analysis that can bridge the gap between theories and applications. These problems cover a wide variety of subjects in the biological and agricultural fields. Specific guidelines and practical methods for defining requirements, developing specifications, and integrating system modeling are included as well.

Computer Simulation Analysis of Biological and Agricultural Systems is a text and a self-guide for agricultural engineers, agronomists, foresters, horticulturalists, soil scientists, and computer simulators.

Catalog No. 4869, 1994

ISBN: 0-8993-4869-2

880 pages/US$159.00

Contact: CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Fl 33431-9868, USA. Tel: 1-800-272-7737, Fax: 1-800-374-3401.

Agricultural Systems Modeling and Simulation

(USA)

---

edited by Robert M. Peart and R. Bruce Curry, University of Florida, Gainesville

Presenting the most recent findings by internationally recognized researchers in the field, this timely book provides an in-depth treatment of modern applications of modeling and simulation in crops, livestock, forage/livestock systems, and field operations — discussing modeling methodologies from linear programming and neural networks to expert or decision support systems as well as featuring agricultural models, such as CROPGRO, GOSSYM/COMAX, GRAZE, and SIMHERD.

Containing current information facilitating the development of new models, Agricultural Systems Modeling and Simulation

Complemented with references, tables, equations, and drawings, including parts of code listings and flow diagrams, this practical volume is a valuable resource for agricultural, biological, and environmental engineers; agricultural systems modeling researchers; agronomists; entomologists; animal scientists; agricultural economists; and graduate-level students in these disciplines.

September, 1997, ISBN: 0-8247-0041-4, 712 pages, illustrated/ US$195.00.

Contact: Marcel Dekker, Inc., 270 Madison Avenue, New York, NY10016 · 212-696-9000.

Chemical and Isotopic Groundwater Hydrology

The Applied Approach, Second Edition

(USA)

---

by Emanuel Mazor, Weizmann Institute of Science, Rehovot, Israel

This unique reference/text, an updated and expanded edition of Applied Chemical and Isotopic Groundwater Hydrochemistry, provides researchers with a thorough understanding of the measurable properties of groundwater systems and the knowledge to apply hydrochemical, geological, chemical, isotopic, and dating approaches to their work.

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442 pages, illustrated/US$150.00

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In-service training on seed conditioning at the Seed Technology Laboratory, Mississippi State University, USA. July-August 1987

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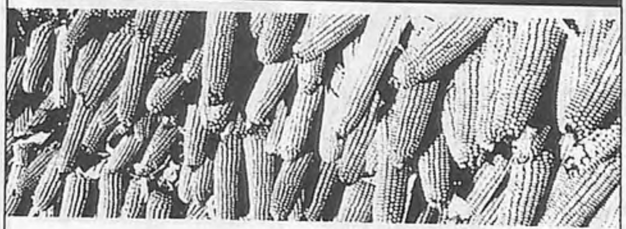

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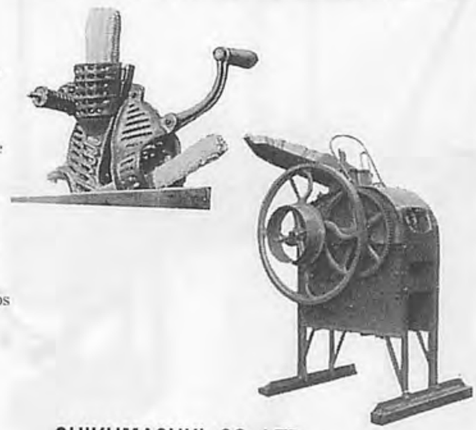

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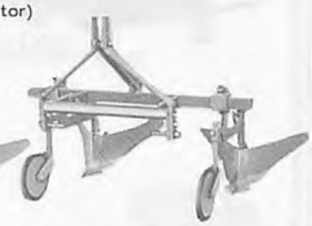

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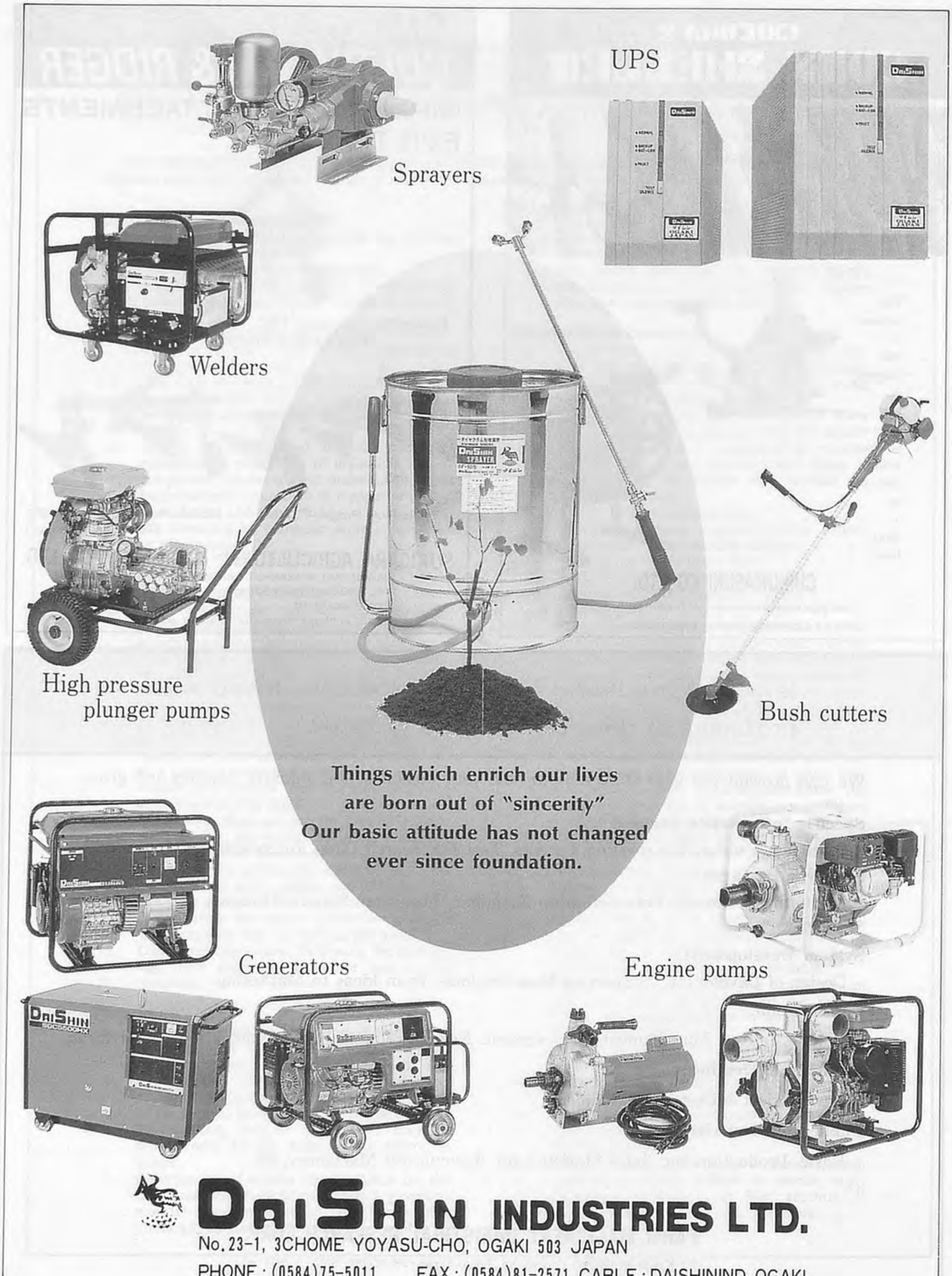
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