International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.37, No.2, SPRING 2006

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.37, No.2, SPRING 2006

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

CIRCULATION

(Tel.+81-(0)3-3291-5718)
(Fax.+81-(0)3-3291-5717)
Editorial, Advertising and Circulation Headquarters
7, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
URL: http://www.shin-norin.co.jp
E-Mail: sinnorin@blue.ocn.ne.jp

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

This is the 127th issue since its maiden isue in the Spring of 1971

EDITORIAL

We had excessively chilly weather in December and January in Japan. In the middle of February, it was warmer than most years and, in Tokyo, the cherry trees began to bloom at the end of March, which was much earlier than in most years. It may have been caused by global warming. In May, soon after cherry blossoms, we had a season of fresh green in Tokyo.

The Symposium on Agricultural Machinery Education, organized by the Japanese Society of Agricultural Machinery, took place in Tokyo in early April. The symposium was primarily concerned with the changes in the agricultural machinery research and educational system within the organizational changes of universities, with respect to the terms of agriculture, agricultural engineering, and agricultural machinery disappearing from the name of university departments.

This is not only in Japan but, also, in advanced nations in Europe and North America. The agricultural research and educational system is, primarily, going to change in advanced nations, while the importance of agricultural development never changes with continued growth of population and concerns about food security. Developing countries are yearning for the transfer of useful agricultural mechanization technology from developed countries. However, the conditions which support such transfer of technology are likely to fade in developed countries. The symposium on agricultural machinery education should be held not only in Japan but also all over the world.

The Japanese term "agriculture" contains the concept of interaction between mankind and other life systems. Sustainable harmonization with other life systems is the only way that mankind can continue to exist on the globe. It should be kept in mind that we can make progress through such harmonization with other life systems or nature.

AMA specializes in agricultural mechanization for developing countries. Mechanization of agriculture will be more important in the future for developing countries. AMA continues to use the key word of "agricultural machinery" in cooperation with all the people concerned.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
May, 2006

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.37, No.2, May 2006

Performance Evaluation of Bullock Drawn Puddlers

by

S. K. Dash
Associate Professor
Department of Farm Machinery and Power,
College of Agric. Engineering and Technology,
Orissa University of Agriculture and Technology,
P.O. Bhubaneswar-751 003, Orissa
INDIA

D. K. Das
Professor and Head
Department of Farm Machinery and Power,
College of Agric. Engineering and Technology,
Orissa University of Agriculture and Technology,
P.O. Bhubaneswar-751 003, Orissa
INDIA

Abstract

This experiment was conducted in the farmers' fields with five bullock drawn puddlers viz. the Implement Factory puddler, the CAET puddler, the APAU puddler, the UP Agro Industries harrow cum puddler and the rotary blade puddler. The pudding operations of these five implements were compared with that of the country plough relative to the puddling index, power requirement, field capacity, puddling efficiency and the cost of operation. The puddler manufactured in the College of Agricultural Engineering and Technology (CAET puddler) was found to be the best with a puddling index of 83.10 percent, energy requirement of 4.38 kwh/ha, field capacity of 0.146 ha/hr, field efficiency of 70.19 percent and operating cost of Rs. 129.17 per hectare. The net energy saving per hectare for this puddler over the country plough was found to be 71.41 percent. This puddler was recommended for use in the farmers' fields.

Introduction

Puddling is the mechanical manipulation of soil in the presence of water to mix fertilizer, manure and plant nutrients with soil uniformly throughout the field to reduce percolation loss of water and to facilitate the transplanting of seedlings by making the soil softer and more level. The puddling operation is performed by the bullock-drawn country plough as the traditional practice and by several improved puddlers. Not only does the puddler do good job churning the soil but, also, the power requirement can be reduced as compared to the traditional method of puddling by country plough working a number of times.

Five bullock drawn puddlers of different makes were procured and the puddling operation was performed in the farmers' fields. The five puddlers were the Implement factory puddler (**Fig. 1**), the CAET puddler (**Fig. 2**), the APAU puddler (**Fig. 3**), the UP Agro-industries disc harrow cum puddler (**Fig. 4**) and the rotary blade puddler (**Fig. 5**). The performance of the above five implements were compared with the country plough with respect to puddling index, power requirement, field capacity, field efficiency, cost of puddling, energy saving and crop yield. The best puddler amongst them was selected and recommended for use in the farmers' fields.

Theoretical Consideration

The evaluation of puddling per-

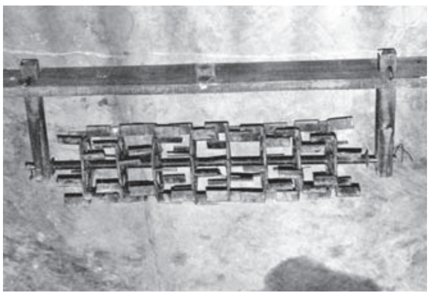


Fig. 1 Implement factory puddler

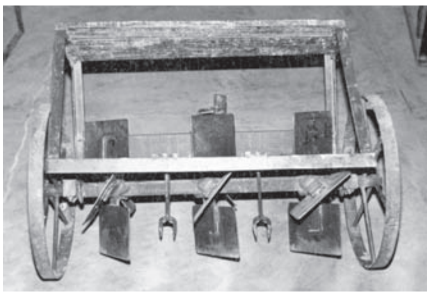


Fig. 2 CAET puddler

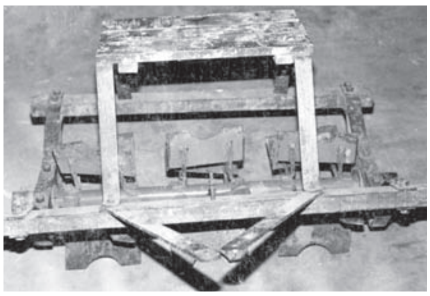


Fig. 3 APAU puddler

formance such as puddling index, field capacity, field efficiency and cost of operation were determined based on the following theory.

Puddling index: The puddling index is the ratio of the volume of settled soil to the total volume of soil sample and is expressed as a percentage.

$$PI = \frac{V_s}{V_t} \times 100 \quad \text{.........................(1)}$$

Where,

PI = puddling index in per cent,

V_s = volume of settled soil and

V_t = total volume of soil sample.

A higher value of puddling index indicates the better quality of puddling.

Theoretical field capacity: Theoretical field capacity is the rate of field coverage that would be obtained if the puddler is operated continuously without interruption such as turning at the ends and unclogging the blades, and is expressed in ha/hr (Equation 2).

Effective field capacity: The effective field capacity is the actual rate of coverage. It includes the time lost from such events as making adjustments, turning at ends and unclogging the blades and is expressed in ha/hr (Equation 3).

The cost of operation was determined by knowing the number of labour and bullock hours used to cover one hectare of land along with the fixed and variable cost of the implement.

Materials and Methods

This test was conducted in the farmers' fields. The farmers provided all inputs and carried out all the operations, as per recommendations, from tillage to harvest. The test plots were selected with uniform size, slope, drainage, soil texture and irrigation facilities. The soil samples were collected and tested before the experiment. The experiment used a RBD design with three replications. Net plot size was 20 m x 15 m. The study was conducted with the following treatments.

T_1 = Ploughing by MB plough + puddling by Implement Factory puddler

T_2 = Ploughing by MB plough + puddling by CAET puddler

T_3 = Ploughing by MB plough + puddling by APAU puddler

T_4 = Ploughing by MB plough + puddling by UPAI disc harrow cum puddler

T_5 = Ploughing by MB plough + puddling by rotary blade puddler

T_6 = Ploughing by country plough + puddling by country plough

The Parijat, Jaya and Ratna paddy varieties were grown. Other inputs like fertilizer, manure, irrigation and pesticide were kept constant for all the experiments.

Results and Discussion

The experimental data were recorded throughout the test for each treatment and the results were analysed. The mean values of puddling indices, field efficiencies, infiltration rates, cost of operations and yields were compared with the mean values for the country plough. Also, the net energy saving and cost over the country plough were calculated and shown in **Table l**. It was found that the highest speed of 2.99 km/hr and draft of 80.81 kgf was observed in T_3 followed by T_2 (2.8 km/hr, 80.72 kgf), T_1 (2.36 km/hr, 77.6 kgf), T_4 (2.06 km/hr, 8l.57 kgf) and T_5 (2.25 km/hr, 56.23 kgf). This speed and draft relationship was due to variation in weights of the implements in addition to the width and depth of puddling.

The effective field capacities for T_1 to T_6 were 0.175, 0.146, 0.156, 0.106, 0.090, 0.014 ha/h, respectively. The least area was puddled by country plough due to increased number of operations and minimum width of coverage. The maximum value of puddling index was T_2 (83.10 percent) followed by T_3 (78.79 percent), T_1 (73.85 percent), T_5 (65.00 percent), T_4 (63.51 percent and the lowest was T_6 (54.85 percent). The highest value of puddling index of T_2 was attributed to better churning of soil by the CAET puddler with widest blade and a blade angle of 30 to 50 degrees. The field efficiencies for T_1 to T_6 were 70.30, 70.19, 68.72, 70.30, 71.20 and 60.40 percent respectively. The maximum depth of puddling was observed with T_2 (19.80 cm) followed by T_3 (l9.38 cm), T_5 (l7.10 cm), T_4 (16.30 cm), T_1 (15.60 cm) and T_6 (8.00 cm). Due to this depth of penetration of the implement the draft requirement was also varied. Comparing the effect of puddling with the grain yield under different treatments, the highest yield was observed with T_2 (17.60 q/ha) followed by T_3 (17.00 q/ha), T_1 (14.41 q/ha), T_4 (l2.3 q/ha), T_6 (9.40 q/ha) and T_5 (9.00 q/ha). This was due to better puddling and provided favourable conditions for better growth of the

$$T_f = \frac{\text{Working width of puddler (m) x Speed (km)}}{10} \quad \text{........................(Equation 2)}$$

$$\text{Field efficiency (percent)} = \frac{\text{Effective field capacity}}{\text{Theoretical field capacity}} \times 100 \text{.....(Equation 3)}$$

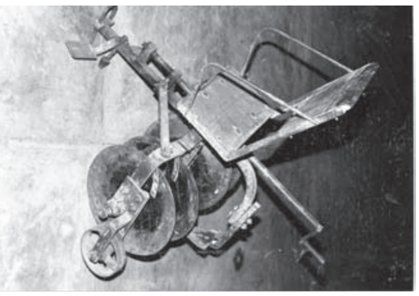


Fig. 4 UP Agro-industry disc harrow cum puddler

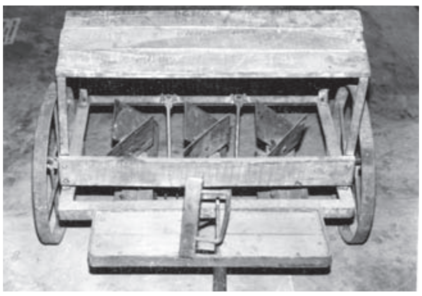


Fig. 5 Rotary blade puddler

crops.

Minimum energy was required for T_1 (2.97 kwh/ha) followed by T_5 (3.94 kwh/ha), T_2 (4.38 kwh/ha), T_3 (4.47 kwh/ha), T_4 (4.50 kwh/ha) and T_6 (21.28 kwh/ha). When the net energy saving for each type of puddler was compared with that of country plough it was observed that maximum energy could be saved for T_1 (86.04 percent) followed by T_5 (81.48 percent), T_2(78.99 percent), T_3 (78.85 percent), T_4 (71.41 percent). The cost of operation per hectare were Rs. 103.14, 129.17, 118.97, 176.41, 211.33 and Rs. 1,210.71 for T_1 to T_6 treatments, respectively. Accordingly the net saving in cost from T_1 to T_5 was Rs. 1,107.51, 1,081.54, 1,091.74, 1,034.30 and 999.38, respectively, in comparison with the country plough.

Conclusion

The results of this study showed that maximum energy saving was achieved with the Implement Factor puddler. However, when it was compared with other puddlers with respect to the puddling index, it occupied the third position. The CAET puddler had the highest value of puddling index with 83.10 percent. From an economic point of view, the Implement Factory puddler was found to be the best followed by the APAU puddler, the CAET puddler, the UPAI harrow cum puddler and the rotary blade puddler. But, comparing all other aspects such as puddling index, power requirement, field capacity, field efficiency and yield, the CAET puddler was found to be the best. This puddler was recommended for use by the farmers of this state for puddling.

REFERENCES

Agrawal M. C., Singh, R., Batra, M. L. and Agrawal, R. P. L978. "Evaluation of different implements for puddling of rice soils", IL RISO, Anme XXVIL, No.4

Awadhwal. N. K. and Singh, C. P. 1981. "Puddling of rice soils: effect of puddling on hydraulic conductivity and pores space". Paper presented at XVIII Annual Convention of ISAE at Kernal.

Annual report of Research and Development Wing.l984-85. Implement Factory, Satyanagar, Bhubaneswar.

Bhole N. G. and Arya, A. C. l964. "Measurement of quality of puddler". Journal of ISAE, Vol 1 (1).

Badhe, V. T., Gupta L. P. and Bhole, N. G. l984. "Performance index for puddler". Paper presented at XXI annual convention of ISAE at New Delhi.

Sl. No.	Parameters	T_1	T_2	T_3	T_4	T_5	T_6
1	Speed, km/h	2.36	2.80	2.99	2.06	2.25	2.10
2	Draft, kgf	77.60	80.72	80.81	81.57	56.23	49.91
3	Time required for puddling one ha, hr	5.73	6.86	6.67	9.42	11.05	69.83
4	Field capacity, ha/hr	0.175	0.146	0.156	0.106	0.090	0.014
5	Theoretical field capacity, ha/hr	0.250	0.208	0.227	0.150	0.024	0.128
6	Field efficiency, percent	70.30	70.19	68.72	71.30	71.20	60.40
7	Width, m	1.06	0.75	0.76	0.73	0.57	0.12
8	Depth of puddling, cm	15.60	19.80	19.38	16.30	17.10	8.00
9	Total energy requirement, kwh/ha	2.97	4.38	4.47	4.50	3.94	21.28
10	Grain yield, q/ha	14.45	17.60	17.00	12.30	9.00	9.40
11	Straw yield, q/ha	30.67	38.80	35.55	30.90	25.70	13.50
12	Puddling index, percent	73.85	83.10	78.79	63.51	65.00	54.85
13	Dispersion of slit clay, percent	16.40	38.10	35.20	9.40	13.60	3.70
14	Total energy per quintal of grain yield, kwh/q	0.205	0.248	0.262	0.365	0.437	2.28
15	Saving of energy, percent	86.04	71.41	78.99	78.85	81.48	-
16	Cost of operation, Rs./ha	103.14	129.17	118.97	176.41	211.33	1,210.71
17	Saving of cost, Rs.	1,107.57	1,081.54	1,091.74	1,034.30	999.38	-

Table 1 Performance results of puddlers

Design of a Knapsack Sprayer for Local Fabrication

by
R. F. Orge
Senior Science Research Specialist
Philippine Rice Research Institute
Central Luzon State University,
Muñoz, Nueva Ecija
Philippine

R. B. Benito
Undergraduate Student,
Central Luzon State University,
Muñoz, Nueva Ecija
Philippine

Abstract

A lever-operated knapsack sprayer with features to improve efficiency and safety in pesticide application was designed and fabricated. The prototype, which was 2 kg lighter than existing Taiwan sprayers, featured a 13-liter capacity plastic tank, a plunger-type pump assembly, a pressure chamber made from PVC plastic pipe, a pressure regulator to control the operating pressure at a pre-set level, and a fine-mist, low-volume nozzle.

At least 50 % reduction in the number of tank loads per hectare could be achieved with the designed sprayer. This enabled farmers to save time in spraying as well as reduce the risk of pesticide contamination every time a spray solution is prepared.

In general, the design of the prototype sprayer was acceptable to the farmers interviewed. Some suggestions were offered by these farmers for further refinement of the design.

Introduction

The use of pesticides has been and will remain both necessary and essential to help meet the increasing need for enough food for the world' s increasing population. Although there have been dramatic advances in pesticide application technology in the past decades, the LOK sprayer is still the principal tool used by our farmers today.

In the Philippines, despite the popularity and high demand of LOK sprayers, there has been no effort to manufacture them locally. In the past, there were about 4 or 5 local manufacturers importing the sprayer parts (stainless steel tank, brass pump and fittings, etc.) and assembling them. But because of the high price of stainless steel, these local manufacturers found it hard to compete with the existing Taiwan sprayer, which is taking much of the market (Yang, 1988 as cited by Resurreccion and Cutay, 1991). Farmers usually buy LOK sprayers on the basis of price with little or no consideration for the choice of nozzle, durability or ease of operation (Matthews, 1990).

Existing farmers' sprayers are equipped with high discharge nozzles suitable for for every hectare treated, and about 200 to 400 liters of water per hectare are needed (Awadhwal et al, 1992). This not only delays the spraying operation, since the 16-liter capacity sprayer tank has to be refilled at least 10 times. It also increases the risk of exposure to pesticide contamination since the operator has to handle the pesticide each time the tank is refilled. Moreover, these sprayers do not have a mechanism to maintain pressure adequate for a uniform nozzle discharge, which is necessary to attain a more accurate and effective pesticide application. This study is, therefore, designed to develop a low cost and easy to fabricate LOK sprayer with features to improve efficiency and safety in pesticide application.

Materials and Methods

Design Criteria

The sprayer was designed based on the following criteria:

Low cost. The design was made as simple as possible to make it easy to fabricate using local fabrication materials, tools and equipment. The ultimate target was to lower the cost enough for it to compete with the price of existing farmers' sprayers.

Easy to repair/maintain. Component parts were designed to be compatible with the existing farmers' sprayers for easy maintenance and replacement of parts.

Durable. This considered the corrosive effects of the chemicals and the mechanical loads of critical parts during operation and handling.

Safe and comfortable to use. Minimizing the operator's risk of pesticide contamination was given prime consideration in designing every part of the sprayer. Likewise, for ease of operation, the sprayer was designed to be as light as possible - not to exceed 20 kg at full tank capacity. The possibility of reducing the force applied at the handle during pumping was also explored.

Efficient. A mechanism that could prevent (or, at least, minimize) pressure fluctuations during operation, regardless of irregular or excessive pumping of the operator, was incorporated in the design. Maintaining the pressure results in a uniform nozzle discharge, which is one important factor reqired to attain the desired amount of pesticide to be applied.

Design of Parts

Nozzle. The design of the CRDI low-volume nozzle (Orge, et al, 1992) was considered and modifications were made to allow for mass fabrication through a plastic molding process. An orifice size of 1.0 mm (Hewitt, 1984) was selected. Component parts of the nozzle were designed to permit easy cleaning (to eliminate the idea of blowing with mouth) when clogging occurred.

Pump. The design of pump components, particularly the cylinder and the plunger, considered the adverse effect of repeated loads during pumping. In the existing sprayers, the pump ranked first in terms of parts that easily get damaged, repaired or replaced (Resurreccion and Cutay, 1991). This was because, of all the parts, it is the one that is exposed to high pressure and repeated load. For farmers' sprayers, the pump cylinder experiences tangential (tensile) stress varying from 0 to 1,000 psi or more for each suction and compression stroke, which is repeated at least 2,400 times for every hectare sprayed.

Pressure chamber. In order to provide a pulsation-free delivery at the nozzle, the capacity of the compression chamber was made at least 10 times the displacement of the pump (Thornhill, 1991).

Pressure regulator. This was designed to complement the nozzle in order to maintain nozzle discharge, even if the operating pressure fluctuates due to excessive or non-uniform frequency of pumping by the operator.

Tank. Designing and fabricating a new tank entailed additional cost, hence, commercially available plastic containers were considered. This required the pump as well as the pressure chamber to be installed outside of the tank, unlike the existing sprayers. Necessary supports were designed to rigidly hold parts in place.

Cut-off valve. A commercially available cut-off valve was used. Various designs are commercially available however; the one that required one-hand manipulation was selected.

Filtering system. The water used in mixing the pesticide usually came from an irrigation or drainage canal that, in most cases, is not free from sand and other impurities. Hence, the need for a good filtering system. The sprayer was designed to accommodate 2 stages of filtering to eliminate, or, at least minimize, clogging.

Testing and Evaluation

The prototype was tested both in the laboratory and in the field. Laboratory tests included determining nozzle and pump performance parameters (discharge, droplet density, angle of swath and volumetric efficiency) at varied operating pressures (15, 30 and 45 psi). Droplet density was determined by counting droplet samples from water sensitive papers (WSP) placed on the ground with the nozzle passing 30 cm above them at about 1 m/s speed. Results were analyzed to determine the appropriate operating pressure of the sprayer, which was the basis for designing and calibrating the pressure regulator.

Field testing was conducted in a 15 m x 40 m plot at PhilRice field with rice plants (manually broadcasted) at booting stage and water level at 3 cm. Volume of spray applied was verified as well as the density of droplets delivered by the nozzle. The density of droplet was determined by collecting droplet samples in the field using water sensitive papers that were placed at a distance above the ground surface equivalent to 50 % of the plant height and 0.5 m horizontal distance apart, for a total span of 8 m perpendicular to the direction of travel of the sprayer operator.

A representative farmers' sprayer (**Fig. 1**) was also tested, along with the designed sprayer to have some basis of comparison. The sprayer was equipped with a twin-orifice nozzle but, during testing, one of the orifices was closed.

Farmers' Participation in Prototype Development

The designed sprayer, after being tested at PhilRice, was brought to eight farmers in Munoz, Nueva Ecija for trial testing in the field. Structured questionnaires were prepared and used as a guide to gather feedback from these farmers regarding the design, operation and performance of the prototype.

Fig. 1 The farmers' sprayer (Taiwan model)

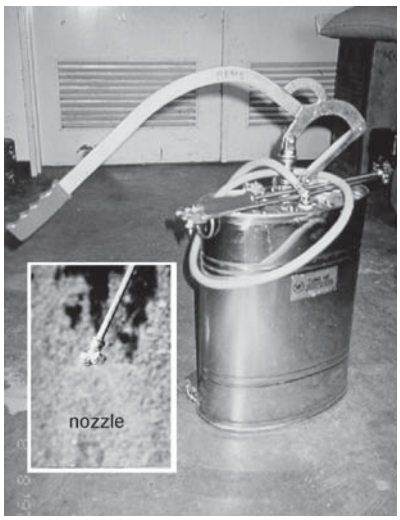


Fig. 2 The designed LOK sprayer

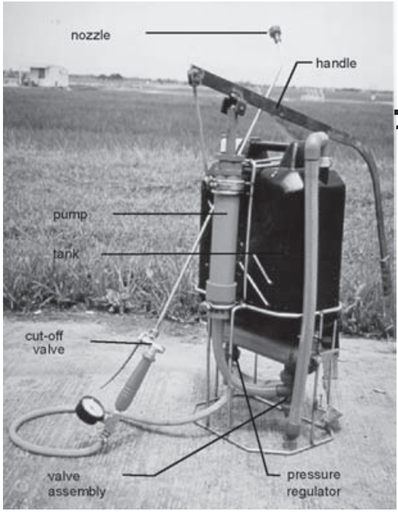
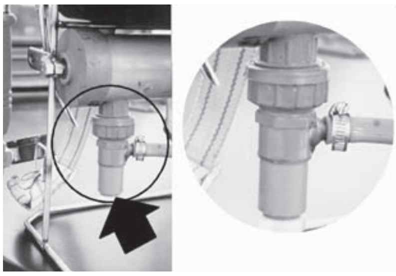


Table 1 Performance of the two LOK sprayers tested at three operating pressures under laboratory condition

Pressure (psi)	Nozzle discharge (ml/min)		Droplet density (no./cm^2)		Swath angle (degrees)		Volumetric efficiency (%)	
	D*	F	D	F	D	F	D	F
15	224.4	476.4	163	113	80	84	64.1	66.1
30	302.4	623.6	203	199	88	88	72.5	74.6
45	360.0	736.8	244	186	88	92	78.6	79.7
Mean	295.6	612.3	203	166	85.3	88	71.7	73.5

*D: designed sprayer, F: farmers' sprayer

Fig. 3 The prototype's pressure regulator



Results and Discussion

The Test Prototype

Figure 2, shows the designed LOK sprayer after several improvements were made in the initial prototypes. Improvements were mainly focused on the design of major parts such as pump, pressure chamber and pressure regulator and their placement with reference to the tank. A major problem encountered and addressed in the initial prototype was the leak at the pump that, because it is installed outside the tank, could cause possible pescitide contamination of the operator.

As shown, the prototype was equipped with a 13-liter capacity plastic container that serves as its tank. The larger opening served as the main inlet while the smaller one served as the suction inlet where PVC fittings and a hose connected it to the valve assembly. The valve assembly controled the flow of the liquid from the tank to the pressure chamber during each suction and compression stroke of the pump.

The pump could be operated by either the left or right hand just like the existing farmers' sprayer. It was equipped with a longer handle to lessen the force of pumping. The pump cylinder, which was made from brass tube (normally sold as a replacement part for the existing farmers' sprayer) was reinforced with fiber glass for durability. It was installed in such a way that, like the plunger, it could easily be removed and replaced by the farmers using simple tools.

A pressure regulator (**Fig. 3**), fabricated from PVC pipe and fittings and other local materials, was connected at the outlet of the pressure chamber. This maintained a uniform pressure of the liquid going to the nozzle, even at varying pressures at the pressure chamber due to irregular pumping.

The prototype was equipped with a hollow cone-type nozzle with parts fabricated from plastic resins using simple molding techniques except the orifice that was made from stainless metal sheet.

The prototype weighed 20.5 kg at full tank capacity, and was lighter than the existing farmers sprayer by 2 kg.

Laboratory Test Results

Nozzle and pump performance. The designed sprayer had a significantly lower nozzle discharge than the farmers' sprayer (**Table 1**). This was expected since the orifice of

Fig. 4 Performance curve of the designed pressure regulator

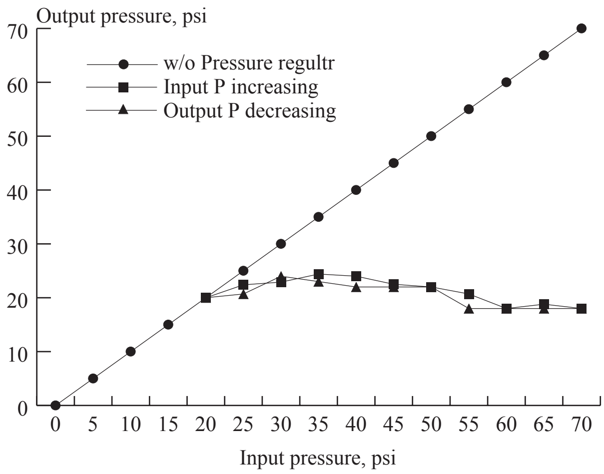


Table 2 Field performance of the two LOK sprayers tested at PhilRice field

Parameter	Designed sprayer	Farmers' sprayer
Spray volume, liters/ha	35	95
Number of tank loads per hectare*	2.7	5.7
Average pumping frequency, strokes/min	16	16
Walking speed while spraying, m/s	0.46	0.65
Width covered per pass, m	3.8	3.4

*Tank capacity
designed sprayer: 13 liters, farmers' sprayer: 16 liters

Table 3 Farmers' comment on performance of the designed sprayer as compared to their existing sprayers

Performance parameters	Better		Same		Worse	
	No.*	%	No.	%	No.	%
Operation						
Pumping operation	5	62.5	-	-	3	37.5
Ergonomics						
Weight	8	100.0	-	-	-	-
Ease of filling the tank	3	37.5	-	-	5	62.5
Ease of cleaning	3	37.5	-	-	5	62.5
Performance						
No. of tank loads	3	37.5	5	62.5	-	-
Uniform discharge	5	62.5	3	37.5	-	-
Size of droplet	4	50.0	4	50.0	-	-
Density of droplet	5	62.5	3	37.5	-	-
Overall performance	-	-	8	100.0	-	-

*Number of respondents having the same comment (total = 8)

the designed sprayer had a 0.5 mm smaller diameter than the existing sprayer. Droplet density, on the other hand, was relatively lower in the existing sprayer as compared to the designed sprayer. Although no actual measurements were done, the droplets in the designed sprayer appeared to be smaller compared to those in the existing sprayer. The two sprayers had comparable volumetric efficiencies.

The only basis for selecting the desired operating pressure was the nozzle performance. The 45 psi pressure produced more fine and drift-prone droplets (as visually observed) compared to lower pressures. Moreover, the pumping force required to maintain such pressure might be too exhausting for the operator. The 30 and 15 psi pressures, on the other hand, could already satisfy the minimum required droplet density set which was 100 to compensate for the 20 droplets/cm^2 minimum requirement in the plant (Hewitt, 1984). However, the angle of swath was relatively low at 15 psi. Follow up tests; however, revealed that operating the sprayer at 20 psi pressure could already satisfy the set requirements.

Pressure regulator performance. As shown in **Fig. 4**, the device's output pressure ranged from 18 to 22 psi for input pressures of 20 to 70 psi. As expected, the output pressure tended to decrease at higher input pressures. The output pressure was adjusted by turning the screw that controls the magnitude of compressive force exerted by its spring on the diaphragm.

Results of Field Tests at PhilRice

Volume applied. Field test results confirmed the significant difference of the volume of liquid applied per unit area between the designed and the existing sprayer (**Table 2**). Although the designed sprayer had a smaller tank than the existing sprayer, with it, the frequency of refilling the tank was reduced by 50 %. This reduction could be more if the walking speeds in operating the two sprayers were the same. During testing of the designed sprayer, however, the operator seemed to swing the lance farther (which resulted to a wider coverage per pass) which could have affected his walking speed.

The reduction in spray volume meant that, with the designed sprayer, a farmer could save time in spraying and, most importantly, reduce the risk of pesticide contamination when handling chemicals when refilling of the tank. If the two orifices of a twin nozzle were used (which was what some farmers were doing), this reduction could be doubled.

Droplet density. Under field conditions, the average droplet density of the designed sprayer was relatively

Fig. 5 Droplet density of the two LOK sprayer tested at PhilRice field (Arrows indicate location where operator passed)

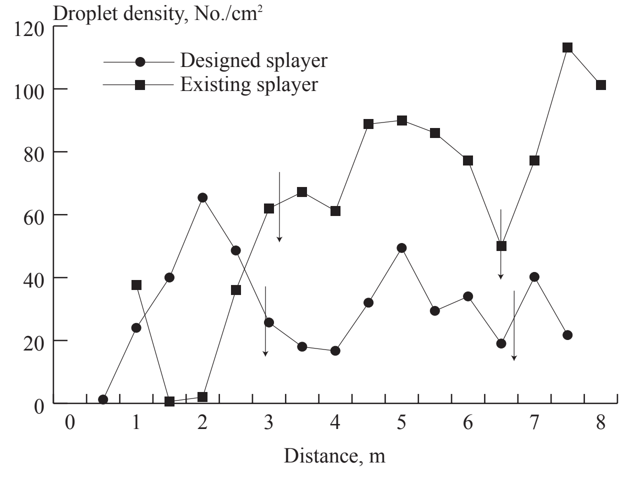
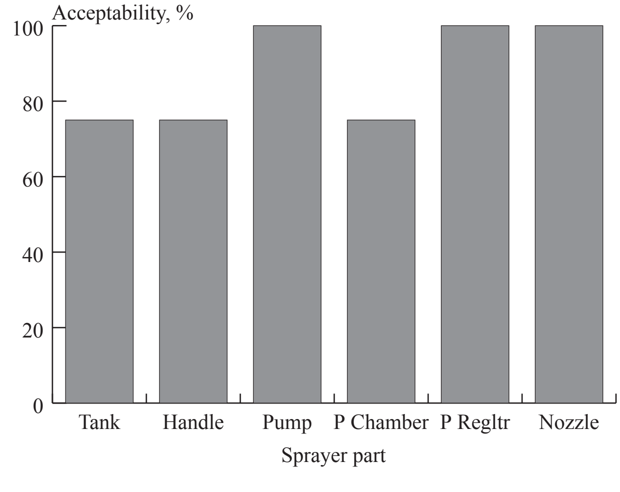


Fig. 6 Acceptability of the design of parts of the prototype sprayer



low as compared to that of the existing sprayer. Like the existing sprayer, however, it satisfied the minimum requirement of 20 droplets/cm^2. The effect of overlapping spray coverage during each pass was more obvious with the farmers' sprayer than with the designed sprayer. This was manifested by the rise in droplet density between operator paths. A more uniform coverage was seen when the droplet density remaind the same at any location relative to the path of the operator.

Results of Farmers' Field Tests

The Respondents

Each of the eight farmer respondents who had tried operating the designed sprayer owned Taiwan sprayers and 2 to 6 hectares of rice farms. They usually sprayed their fields 2 to 3 times each cropping period at 6 to 8 tank loads (16 liters per tank load) per hectare.

Farmers' Comments

On performance. All of the farmer respondents noticed the advantage of the designed sprayer as being lighter than their sprayers. Five out of the eight respondents also noted that the designed sprayer was easier to pump and had a better nozzle performance compared to their sprayers. In their overall assessment, they found the performance of the designed sprayer comparable to their sprayers (**Table 3**).

On design. In general, the design of the prototype parts were acceptable to the farmer respondents (**Fig. 6**). Of all the parts, the pressure regulator, the nozzle and pump were the most acceptable to them. Some suggestions, however, were given for further improvement of the design (**Table 4**). The most common suggestion was on increasing tank and pump capacity and placing the pump inside of tank. Some wanted a cover for the pressure chamber for safety and aesthetic reasons. Half of the respondents suggested a longer hose and lance for the designed sprayer.

Conclusion and Recommendations

This study was designed to develop a low cost and easy to fabricate LOK sprayer with features to improve efficiency and safety in pesticide application.

Results of field tests revealed that the performance of the prototype sprayer was better than that of the existing sprayers commonly used by the farmers. This was further confirmed when the prototype was tested by selected farmers. The suggestions of the farmer respondents may be already sufficient to come up with the final design of the sprayer although additional tests at farmers' fields and gathering of feedback would be more appropriate.

Table 4 Farmers' suggestions for further improvement of the prototype

Sprayer part	Suggestions for improvement	Frequency*	
		No.	%
Tank	Increase tank capacity	6	75.0
	Widen tank inlet	2	25.0
Handle	Modify shape so as not to touch the shoulder and back while pumping	4	50.0
Pump	Increase pump capacity	6	75.0
	Pump should be inside of tank	6	75.0
Pressure chamber	Provide cover	5	62.5
Nozzle	Adjustable nozzle	1	12.5
Delivery hose	Increase length	4	50.0
Lance	Increase length	5	62.5
Connections	Threaded connections for durability and leak proofing	1	12.5

* Total n = 8

REFFERENCES

Awadhwal, N. K., G. R. Quick and E. F. Cabrido. 1992. Spinning brush very-low-volume pesticide applicator. Paper presented during the 42nd PSAE Annual National Convention held at MMSU, Batac, Ilocos Norte.

Hewitt, L. M. 1984. Spray application technology. Mimeographed.

Matthews, G. A. 1990. Visit to IRRI. A consultancy report (mimeograph).

Orge, R. F., L. T. Pascua and D. Castro. 1992. Design and development of a low-volume sprayer nozzle. Paper presented during the 42nd PSAE Annual National Convention held at MMSU, Batac, Ilocos Norte, April 22-24, 1992.

Regional Network For Agricultural Machinery. 1983. RNAM test codes and procedures for farm machinery. Technical Series No. 12.

Resurreccion, A. N. and S. M. F. CUTAY. 1991. Paper presented to the workshop on small sprayers standards, safety and future direction, November 18-20, Bombay, India.

Thornhill, E. W. 1991. Some views on side lever knapsack sprayers. Paper presented to the workshop on small sprayers standards, safety and future direction, November 18-20, Bombay, India.

■■

Current and Future Trends and Constraints in Iranian Agricultural Mechanization

by
Ahmad Tabatabaeefar
Associate Professor
Head of Agricultural Machinery
Engineering Department
University of Tehran,
Karaj, IRAN
atabfar@ut.ac.ir

Ali Hajeiahmad
Agricultural Machinery
Engineering Department
University of Tehran,
Karaj, IRAN

Abstract

Iranian agricultural mechanization continues to experience a lack of technical or scientific management, or mismanagement in general. What does the future hold? The key objectives of this study were to identify farming power, estimate the inventory of agricultural equipment at the farming household level, and to identify the status of manufacturing, sales, and services and the constraints and opportunities for improvement, particularly in agricultural mechanization and production.

There are two main farming systems in Iran; irrigated and rain fed (dry land). The main crops are wheat, oats, peas, alfalfa, and rice. There are three types of farming power and farming households.

For agricultural mechanization development, the government must support more research and development opportunities, hire qualified youth and willing graduates and increase international cooperation. Increased financing of agricultural machinery manufacturing is also necessary along with the distribution of tractor power based on regional, technical needs. A program of expansion and education should be developed. Government policy that hinders development in rural areas at the expense of the migration of human resources and capital investment must be avoided.

Introduction

Iran is 1.65 million square kilometers in size and is 25º to 47º latitude and 39º longitude, north of the equator. The average elevation is 1,200 m above sea level with the lowest elevation being Lootchaleh at 56 m above sea level and the highest elevation being at Mt. Damavand at 5,610 m. The country currently has 30 provinces and 282 major cities. Climatic conditions are desert and semi-desert with 30-250 mm annual rainfall, along with cold and moderate mountainous regions. Cold mountainous regions average over 500 mm annual rainfalls and encompass an area of 40,000 square kilometers. Moderate mountainous regions, which cover about 300,000 square kilometers of the country, average 250-600 mm of rainfall annually. A narrow strip of northern Iran between the Caspian Sea and the Alborz Mountains has an annual rainfall of 600-2,000 mm (MAJ, 1999).

Iran has over 14.9 million hectares of agricultural land, with 12.4 million hectares under annual crops and approximately two million hectares of horticultural trees. The two main farming systems are irrigation (41.9 %) and rain fed (dry land; 41.2 % (MAJ, 2004). The Azarbayjan province has the highest percentage of cultivated land at 8.9 % of total (MAJ, 2004).

The total area under cultivation and the timeliness and efficiency of crop husbandry is strongly influenced by the amount of available farm power and its efficient use. The increased usage of farm power for cultivation creates increased demand for agricultural machinery for harvesting and storage and generates employment opportunities in the agricultural service industry. It is therefore important to establish the quantity of available farm power and its application in various agricultural activities (soil preparation, sowing, weeding, spraying, harvesting, processing, etc). The key objectives of this study were:

- To identify the farming power sources in the country (manual, animal and motorized), their relationship to farming systems, and how they are expected to change in the near future.
- To estimate the inventory of agricultural equipment at the farming household level.
- To identify the amount of agricultural equipment that is manufac-

Table 1 Principal crops and area under cultivation

Principal crops	Year 2004		
	Total output ('000t)	Yield (t/ha)	Area ('000ha)
Wheat	14,568	2.20	6,608
Oats	2,940	1.84	1,600
Rice	2,542	4.16	611
Cereal	21,977	2.42	9,092
Alfalfa	4,367	7.38	592
Melon	3,748	19.91	188
Pistachio	185	0.43	431
Pomegranate	692	11.16	62
Circus fruits	4,121	15.67	263

Table 2 Share of principal farming systems

Principal farming systems	Year 2004	
	Area ('000ha)	Percent of total arable area
Irrigated	6,255	41.94
Dry land*	6,145	41.21
Permanent crop**	2,513	16.85
Total	14,913	100.00

*Dry land: rain fed
**Permanent crop: horticulture

tured locally or imported and the available service facilities.

• To identify the constraints and opportunities for improvement in the sustainable livelihood of farming households, particularly in relation to agricultural mechanization and agricultural production.

Overview of the Current Economic and Social Situation

Iran has a population 68 million and an overall agricultural force of 23,806,251 (35 %) (Third Yearbook of Agriculture, 2004). The number of people engaged in agriculture increases at a rate of about 15 %. However, since the urban population increased 42.6 % over the past 10 years, it is evident that people are moving out of rural areas to the cities. Reasons for this migration are the occupational opportunities, social services and the development of a thriving black market. Also, the cost of living for farmers is frequently higher than their annual income. Iranian population has increased 3.1 % over past 10 years, however the percent employed has not increased at the same level, indicating an 18.9 % increase in the unemployed. The agricultural sector contributes 20.04 % of the gross national product, which is relatively low with respect to the service sector (Mojtahedi, 1996, MAJ, 2000, MAJ, 1998-01).

Average farm size is about five hectares and has an annual yield of 3,500 kg of wheat per hectare, which sells for about 11.76 million rials. This is barely a subsistence level. Farmers increase their income with the sale of other goods or with a second job to make ends meet. Some farmers have cash crops, which amount to 30-40 million rials per year. There has been an export of about 969 thousand tons agricultural commodities with a value of 683 million dollars. This reflects a 5 % increase relative to 1999 (MAJ, 2000). There have been 2-3 years of drought, which has strongly affected agriculture. Agricultural costs have increased sharply, which has put such a high cost for the production of some crops that they are unreasonable to produce. There has been a definite increase in greenhouse production recently.

Methodology and Results

1. Farming Systems, Farming Households, Agricultural Production, and Farm Power Sources

The main crops are wheat, oats, peas, alfalfa, and rice, each utilizing more than 500,000 hectares (MAJ, 1997-01, 2000, 2004). There are three types of farming power available: human, animal and motorized (single and twin axle tractors) (Tabatabaeefar, 1998).

1.1 Principal Crops and Area Under Cultivation

Wheat, oats, peas, alfalfa, and rice have average yields, in both systems, of 2.4, 1.84, 2.37, 7.38, and 4.16 tons/ha respectively, as shown in **Table 1**. Citrus fruits, apples, pistachios and dates are the main horticultural crops (MAJ, 1997-01, 2002, 2004 and Personal interviews, 2002).

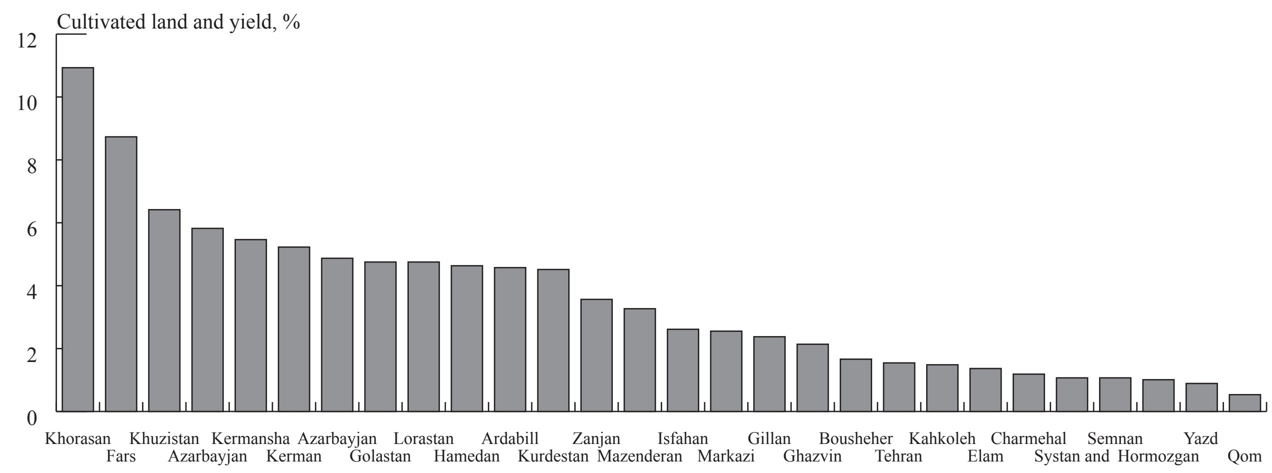


Fig. 1 Cultivated land and its yield by province

Table 3 Distribution of farming systems by farming household

Principal farming systems	Farming households: Small – No. of Households (‘000)	Small – (‘000ha)	Small – Percent of total area	Medium – No. of Households (‘000)	Medium – (‘000ha)	Medium – Percent of total area	Large – No. of Households (‘000)	Large – (‘000ha)	Large – Percent of total area	Total – (‘000ha)	Total – Percent of total area
Irrigated	2,381	2,108	35	2,158	2,409	40	1,202	1,505	25	6,022	100
Dry land	NDA	1,578	25	NDA	1,263	20	NDA	3,473	55	6,314	100
Total		3,686	30		3,672	30		4,978	40	12,336	100

NDA: No date available

Khorasan province has the highest percentage of annual crops, with 10.93 % of the total cultivated area, followed by Khuzistan, Azarbaijan, Fars, Loristan, and Kordestan provinces. These six provinces account for 42.6 % of the total cultivated land. Tehran, Isfahan, Mazanderan, Kerman, and Gilan provinces have higher yields per land area. The total annual crop production is 47.62 million tons, with 87.19 % from irrigated land and the rest from dry land farming. Other provinces have lower output, as shown in **Fig. 1** (MAJ, 1998-01, 1997-01, 2000, 2001, 2004). **Figs. 2** and **3** show grain and cereal yields per province. The central provinces yield about 4 million tons of grain, with the Lorastan province having the highest yield.

1.1.1 Principal Farming Systems

Irrigated and dry land crops total 41.94 % and 41.21 %, respectively, as shown in **Table 2**. Under both farming systems, small farm holdings, tenant farming, share cropping, cooperatives, and government-industrial cooperatives exist.

1.1.2 Principal Farming Systems and Farming Households

Distribution of farming systems by farming household is shown in **Table 3** for small, medium and large scale farming. Small-scale farmers rely more on manpower and less on other power. These small-scale farms are less than two hectares and account for 7-83 % with about 35 % irrigated and 25 % dry land. The average-farming households are 1.3-5 people. (Personal interviews, 2002 and Tabatabaeefar, 2002).

1.1.3 Principal Farming Systems, Power Sources and Conservation Agriculture

Irrigated farming uses all the three power sources, but mainly the tractor twin axial as shown in **Table 4**. Single axial tractors are extensively used in paddy fields. There is some traditional agriculture; however, the trend is towards less human and animal power and more tractor power in annual crop agriculture. In irrigated farming, the average wheat yield is about 3,195 kg/ha (MAJ, 2000).

Dry land farming system uses all the three power sources. Some farmland is steep or hard to reach and the distribution of farmland is non-uniform. In these cases, there is more reliance on human power. Principal dry land farming will show an increase in the use of twin axial tractors in the future. There has been some indication of this from 1995-2000 that shows a decrease in human power sources. The average wheat yield is about 593 kg/ha in dry land farming (MAJ, 2000).

Conservation agriculture is not strongly considered in Iran. There is a hope for the future since production is not increasing and the soil is becoming less fertile.

Virtually every farmer has a shovel and a hoe and some have tractors but most use rented tractors. A small number of households use single axial tractors.

Greenhouses provide higher income and higher yields in a smaller area. However, crops are sprayed

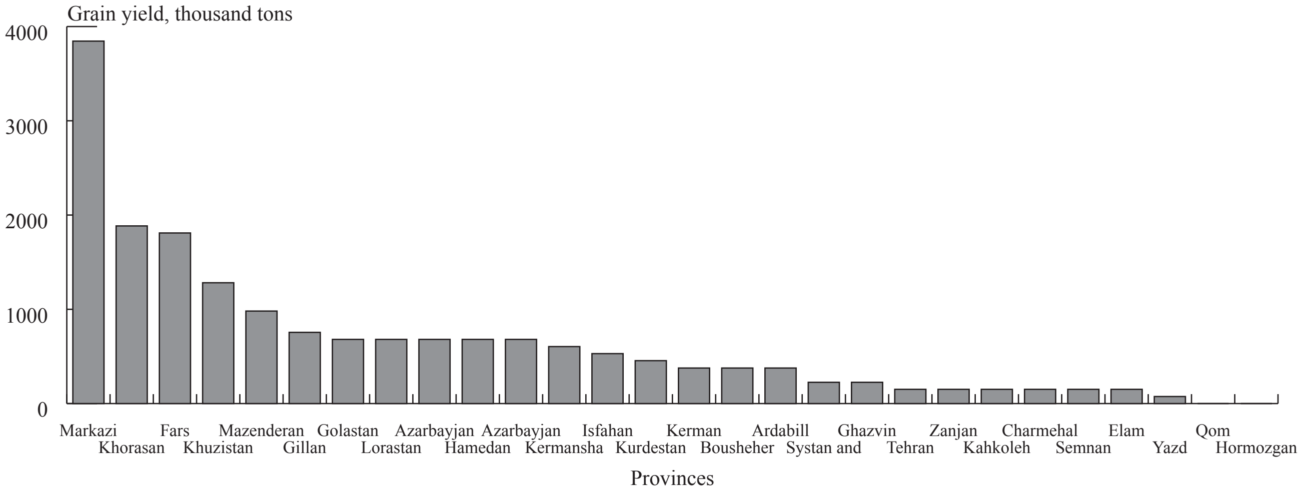


Fig. 2 Grain yield by province

Table 4 Principal irrigated farming systems

Year	Propotion of arable area in each farming system cultivated by power source (%)					Propotion of arable area under conservation agriculture
	Hand	Draft animals	Tractors single axle	tractors twin axle	Total	
1995	14	5	3	78	100	
2000	12	3	2	83	100	Almost none
2005	10	1.5	2	86.5	100	
2010	8	0.75	1.75	89.5	100	About 15 percent

up to 20 times to protect against disease. Other methods of disease protection must be investigated. The high percentage of human power in greenhouse crops (64 %) will be replaced by motorized power.

2. Inventory of Farm Power Sources, Tools and Equipment

All types of tractors, from single axial to crawler tractors, exist in the country. The majority of tractors are 60-80 horsepower, as shown in **Fig. 4** (MAJ, 2001), and are 4-18 years old (Tabatabaeefar, et al., 2002). Some new tractors have recently been distributed. Universal tractors account for 53 % with 41 % being Massy Ferguson and a few John Deere models (MAJ, 2001). A large number of animal types are available to the farmers as shown in **Table 5**. About 35 % of the population works in agriculture with 86 % being male and 14 % female as shown in **Table 5** (Third Yearbook of Agriculture, 2001).

Five to 20 kW diesel engines are primarily used for irrigation. A small amount of processing machinery is available. It is very likely that this will increase because of the decreasing human and animal labor pool. On small farms, most of the processing is done by human labor, but this trend will change with more processing machinery being used. About 98 % of the primary tillage of some agricultural crops is now done by machine (MAJ, 2001, Tabatabaeefar, 1998).

2.1 Inventory of Farm Power Sources

In 2001, 1,192 tractors and 30 self-propelled harvester combines were produced (Ministry of Industry and Mining, 2001). In 2000, 7,474 tractors, 363 combines, 230 self-propelled harvesters, 1,024 tillers, 733 moldboard ploughs, 138 disks, 388 seed broadcasters, 141 deep seeders, 281 sprayers, 31 choppers and 52 milking machines were distributed (MAJ, 2000). Khuzistan province received 8.7 % of the moldboard ploughs and Ilam province received 13.5 % of the combines distributed. Of the tractors distributed, 82 % were MF 285 models (Tractor Manufacturing Corp.) and 0.7 % was Darvana models (MAJ, 2001).

2.2 Inventory of Tools and Equipment at the Farming Household Level

About 87% of farmers own twin axial tractors with soil inverting implements and hand tools for primary tillage, and 92 % do secondary tillage with tractor driven implements. About 87 % of farms own manual planting equipment (MAJ, 2001, Personal interview, 2001).

2.2.1 Overall Percentage of Farming Households Owning Items

For manual primary tillage, about 72 % of farming households own hand tools, 22 % own draft animals and hand tools, and 6 % own single-axle tractors and hand tools. The total of primary tillage hand tools was estimated at 4,601. Farms owning twin axle tractors and hand tools for tractor-drawn primary tillage soil inverting (moldboard plough, disk plough) and soil non-inverting, (chisel plough) totals 230,573.

Iranian farmers most frequently use operator-carried sprayers. Operator-carried spray equipment totaled 77,587 number and 59 % of farms owning tractors and hand tools have operator-carried sprayers. About 77 % of farms owning twin axles tractors and hand tools (FHTATH) have tractor-operated spray equipment, totaling 15,709 households. About 8,750 self-propelled combine harvesters are primarily for hire.

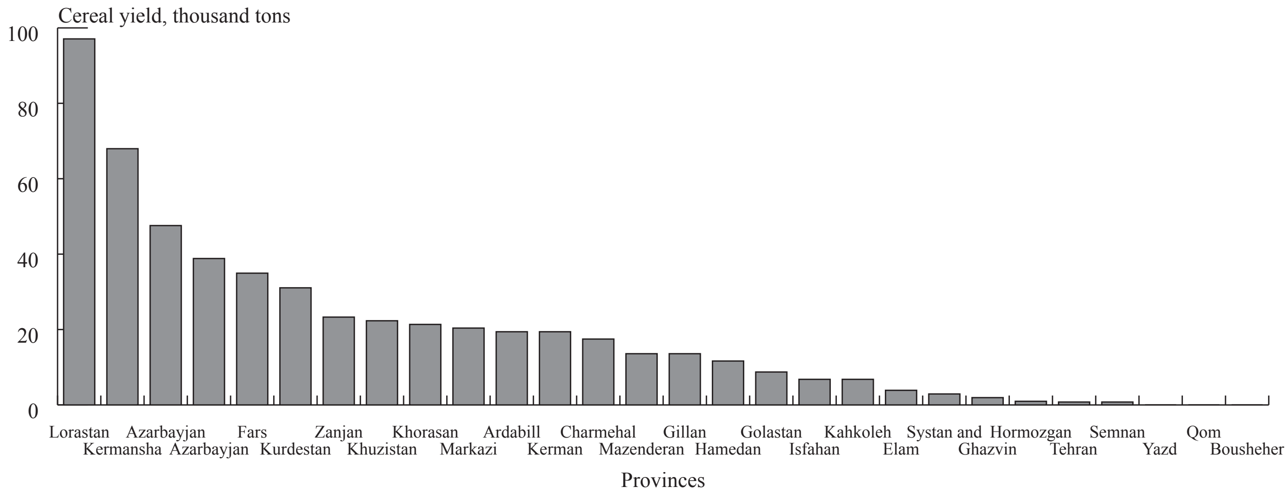


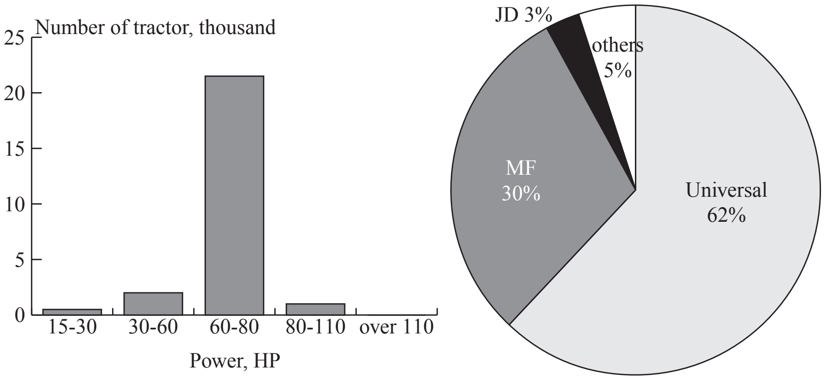
Fig. 3 Cereal yield by province

A strong union in Shiraz harvests from the south to the north of Iran over a three-month period, but most of these combines are old. There are 6,627 John Deere combine harvesters, 686 Class combines and 940 other types. Motorized post harvest equipment accounts for 59 % of FHTAT (52,614).

Most transport is hired but 66 % of farming households own draft animals and hand tools (FHOADPH). FHADPH use manual transport. A total of 405,558 (82 %) FHTATH use irrigation pumps. Surface irrigation is common, covering 7,593,600 hectares. Sprinkle and drip irrigation has recently been introduced, but with little success. Parts and filtration systems and the cost of layout are the main obstacles (P.I., 2001).

2.2.2 Inventory of Tools and Equipment of Typical Farming Households

Fig. 4 Tractor power and tractor model distribution (2004)



(a) Tractor power **(b) Tractors by model**

About 15 % of human power is used in areas with steep slopes and hard to reach areas. About 2 % of farms use animal power and the rest use mechanical power (Tabatabaeefar, 1998). However, a good percentage of the farms using human and animal power needed tools that are made locally, especially threshers. Single axle tractors with the needed accessories have recently been manufactured in Iran. Farming households owning tractors are about 65 % and most moldboard ploughs, disks, planters, tractor-drawn sprayers and harvesters are made locally.

Labor and power sources to year 2000			Numbers
On-farm manual labor	Number of farming households		5,711,000
	Number of active female farming households		766,000
	Number of active male farming households		4,945,000
Animal traction	Oxen & cows		218,000
	Buffalo		-
	Horses		130,000
	Donkeys		1,177,000
	Mules		116,000
	Camels		87,000
	Others		200,000
Tractors	Single axle		123,842
	Twin axle	Up to 40 kW	25,181
		40-100 kW	211,981
		Above 100 kW	539
		% FWD	18
	Clawler		9
Motors for crop processing (Estimate of equipment in use)	Electric	Up to 3 kW	-
		3-10 kW	113,536
		Above 10 kW	-
	Diesel/Petrol	Up to 3 kW	-
		3-10 kW	-
		Above 10 kW	10,000
Motors for irrigation processing (Estimate of pumps in use)	Electric	Up to 5 kW	-
		5-20 kW	11,133
		20-50 kW	12,986
		Above 50 kW	9,380
	Diesel/Petrol	Up to 5 kW	-
		5-20 kW	242,409
		20-50 kW	59,785
		Above 50 kW	69,859

Table 5 Number of households and available power sources

2.3 Inventory of Equipment at Typical Village or Community Level

In 2000, agricultural machinery distributed totaled 3,068 units, whereas in 1993 the total was 18,859 units (MAJ, 2001). The number of tillers declined from 1,054 to 21 units because the area of the arable land has not changed and is not needed. The number of sprayers distributed was 5,333 units in 1993. In 2000, it was 281 units (MAJ, 2001).

The government instituted two five-year development programs, which are known as the second and third five-year programs (MAJ, 2001). The third five-year program ends in 2006. The core of the mechanization development plan aims at a higher degree of mechanization through the production and advertisement of machinery and the pursuit of internal governmental support. The degree of mechanization for planting was 26 % in 2000 and the third five-year program aims to increase that to about 50 % (MAJ, 2001). This program is progressing slowly.

3. Manufacturing, Imports, Exports, Sales and Servicing

There are over 1,500-farm machinery outlets (MAJ, 2001) with adequate inventory and reasonable prices. Producers must lower both the quality and price of their products in order to make them attractive for sale. Some farm machinery plants have tried exporting goods, but have met with little success.

Farmers receive loans through the Keshavarzi Bank to buy machinery. There are three factories that produce tractors, two producing engines, two producing tillers and one producing self-propelled and tractor-drawn harvesters. Depending on the factory, most important parts (5-95 %) are imported (completely knocked down-CKD) and the machine is assembled in Iran. In 2000, about 628 motor pumps were sold (insufficient information on power type). There are about 3,797 stationary and 629 mobile maintenance and repair shops (MAJ, 2001).

3.1 Count and Value of Agricultural Power Sources, Tools and Equipment

Tractors of 7.5-80 hp are mostly produced in Iran, some by joint venture. Higher horsepower tractors are ordered through the license and CKD system. Electric motors are mainly imported, although some are made in Iran, but diesel motors are mainly made in Iran (insufficient information on motor types). All prices are coded in rials at the official rate of $1 = 9,000 rials. This price may change when the official rate increases, as has been proposed. The total value of power sources sold over one year was $547.2 thousand dollars. Agricultural equipment and tools sales were $4,965.6 thousand dollars.

3.2 Manufacturers of Agricultural Equipment

Several main factories produce tractors, engine, tillers, self-propelled harvesters, and combines. A list of top producers (Personal interview, 2001) is as follows:

• Tractor Sazi Company: this company produces tractors of 46 to 110 horsepower with total capacity of 20000 units. There is another group within this company called Motorsazan that produces engines for tractors, ships, and boats.

• Combine Sari of Iran: this Company produces combines, mowers and balers with a value of $0.94 million.

• Eshtad Iran: this Company produces 7.5-13 horsepower tillers with a value of $0.81 million.

Most agricultural machinery, especially 7.5-110 hp tractors, are produced in Iran. Nearly 100 % of primary tillage and a high percentage of secondary tillage machinery have been produced either officially or unofficially in the country. There is little importing, with the exception of some machinery parts.

3.3 Marketing, Sales, Servicing and Support Services to Agricultural Mechanization

The Centre for Development of Agricultural Mechanization of the Ministry of Agricultural Jihad sells some machinery to the farmer. Its agents are private and also sell other products from private companies. Unfortunately there is no serious servicing and supporting services from the manufacturers (shown in **Table 6**). However, the agents themselves provide good maintenance and services to farmers. A system of direct buying and servicing must be provided.

Strengths (S)	Weaknesses (W)
Factors relating to agricultural mechanization that promote its development in the country.	Factors relating to agricultural mechanization which hinder its development in the country.
Plentiful fossil fuels and solar energy sources, Suitable human resources, Variable climate conditions, Water and soil resources, Marginal waste area of land, Improved industry and services, Suitable beds of technology improvement, Overall mechanization study carried out, Second and third five-year programs	Lack of farm-based policy for mechanization development, Lack of proper extension services, Poor distribution of governmental dicision-making bodies responsible for agricultural development, Partial success of five-year programs, Lack of large-scale farms, Lack of control over services and repair, Lack of private agricultural mechanization groups, No uniform distribution of tractor power
Opportunities (O)	**Threats (T)**
Factors external to agricultural mechanization that may present new opportunities for its development in the country.	Factors external to agricultural mechanization that may present new threats to its development in the country.
Fallow areas to produce new markets in Asia and the Middle East for agricultural products, Research and development opportunities, Marginal areas of land that can be improved by mechanical power, Young and willing educated graduates, International cooperation	Unsuitable technology transfer, Government policy which may hinder development in rural areas at the expense of migration of human resources and capital investment, Increased cost of technological services, Reduction of cash flow to agricultural machinery manufacturers

Table 6 Strengths, weaknesses, opportunities, and threats (SWOT) to development of agricultural mechanization

4. The Future for Agricultural Mechanization in Iran

The Centre for Development of Agricultural Mechanization has tried through the five-year programs and other plans to support mechanization development. They have observed testing of new foreign or Iranian-made machinery. They have provided education and extension services. There is still a need for serious planning, testing, teaching, and training cycles.

A serious drawback to the agricultural machinery production system is cash flow. The farmer cannot get a quick loan to buy what he needs and may not be able to make payments in lean years. The government should consider supporting the farmer through the purchase of goods and subsidies.

Conclusions

The Centre for Development of Agricultural Mechanization is working toward a better degree of mechanization by producing the needed machinery and advertising mechanized farming systems and instituting government support for production. In 2000, the degree of mechanization for planting was 26 % and the Centre believes it will be 50 % after the conclusion of the second five-year program. These programs are progressing slowly.

A few factors strengthen agricultural mechanization, such as ample fossil fuels and solar energy sources, suitable human resources, a variety of climate, water and soil resources and marginal waste of land. However, the lack of farm-based policy for mechanization development, lack of proper extension services, the distribution of governmental decision-making bodies responsible for agricultural development, and the inefficient use of agricultural machinery have made the two five-year programs only partially successful.

For agricultural mechanization development, the government must support more research and development opportunities, hire qualified youth and willing graduates, and increase international cooperation. Increased financing of agricultural machinery manufacturing is also necessary, along with the distribution of tractor power based on regional and technical needs.

A program of expansion and education should be developed. Government policy that hinders development in rural areas at the expense of the migration of human resources and capital investment must be avoided.

Acknowledgements

The author extends his appreciation to University of Tehran and to the Ministry of Jihad Agriculture.

REFERENCES

Agricultural Experts Group. 2001. Third Yearbook of Agriculture in Iran, pp. 345-370.

Food and Agriculture Organization, 1995. World Agriculture: Towards 2010. John Wily and Sons, Chichester, New York, Brisbane, Toronto, Singapore.

Ministry of Agricultural Jihad., 1998-2001. Agricultural Statistical Investigations Booklet. publication no. 77/01.

Ministry of Agricultural Jihad, 2000. Agricultural Statistics Booklet. Publication no. 79/15.

Ministry of Agricultural Jihad, 2001. Agricultural Statistics Booklet, publication no. 80/03

Ministry of Agricultural Jihad, 1997-01. Iran Agricultural Information Bank. Publication no. 76/01.

Ministry of Agricultural Jihad, 2000. Iran Agricultural Information Bank, publication no. 79/17.

Ministry of Agricultural Jihad, 2000. Centre for Development of Agricultural Mechanization Overview of Agricultural Mechanization, Bahman, 1379.

Ministry of Agricultural Jihad, 2001. Centre for Development of Agricultural Mechanization Agricultural Machinery Producers Booklet, Esfand, 1380.

Ministry of Agricultural Jihad, 2004. Centre for Development of Agricultural Mechanization Agricultural Machinery Producers Booklet, Esfand, 1383.

Ministry of Agricultural Jihad, 2000. "Centre for Development of Agricultural Mechanization. CD of information, a complete bank of agricultural mechanization."

Ministry of Agricultural Jihad, 2004. "Centre for Development of Agricultural Mechanization. CD of information, a complete bank of agricultural mechanization."

Ministry of Industry and Minerals, 2000. Summary of Performance of the Ministry of Industry and Minerals, Bahman, 1380

Ministry of Industry and Minerals, 2004. Summary of Performance of the Ministry of Industry and Minerals, Bahman, 1383

Mojtahdi, A., 1996. "Department of Economic Development of the Majlis: population and occupation." Majlis and Pazhouhesh Magazine, pp123-130.

Tabatabaeefar, A. and Almasi, M., 2002. Farm Power Study in Iran. Project No. PO- 112515-2002. 1-25, Report to FAO-AGSE. 1 report.

Tabatabaeefar, A., and A. Javadi, 2004. Sustainable Tillage Methods in Irrigated Wheat Field for Different Regions of Iran. ASAE/CSAE annual international meeting of Agricultural Engineering. ASAE Paper No. 040117. August 1-4, 2004. Ontario, Canada.

Tabatabaeefar, A. 2004. Agricultural Mechanization development parameters. International Conference on Agricultural Mechanization Development Methods, Karaj- Iran. 21-22 December

Tabatabaeefar, A., Nowrouzieh, Sh. and Ghorbaninasar, G., 2005. Impact of Alleviation of soil compactness on water use and yield of cotton. International Journal of Agriculture and Biology. (ISI Journal) 07-6:885-888. Friends Science publishers.

Tabatabaeefar, A. and Omid, M. 2005. Current Status of Iranian Agricultural Mechanization in. International Journal of agriculture and social sciences 2: 196-201. Friends Science publishers.

Tabatabaeefar, A., Ahmadi, M., Borghei, A.M., 2002. "Model of repair and maintenance cost of tractors in Kermanshah", Journal of Agricultural Science, Azad University Research and Science Unit, vol. 30, pp 12-20.

Tabatabaeefar, A., 1998. "Comparison of agricultural mechanization in Iran relative to other countries" Proceedings of the 7th International Conference of Energy and Mechanization, Adana, Turkey.

■■

Comparative Evaluation of the Performance of Intermediate Agricultural Processing Technologies with Traditional Processing Techniques for Cereal Crops in South Africa

by

V. I. O. Ndirika
Senior Research Fellow / Senior Lecture
Department of Agricultural Engineering,
Institute for Agricultural Research,
Ahmadu Bello University, Zaria
NIGERIA

A. J. Buys
Professor and Director
Institute for Technological Innovation,
Faculty of Engineering University of Pretoria
South Africa

Abstract

An evaluation of the performance of a (1) tractor powered maize sheller and shelling with tractor wheels; and (2) electrical and diesel operated sorghum milling machines compared with traditional maize shelling and sorghum milling techniques was conducted at Vergelegen rural community in the Northern Province of South Africa.

The performance of the maize shellers and the traditional shelling techniques were evaluated in terms of shelling efficiency, grain output and grain damage, while the sorghum milling machines and the traditional milling techniques were evaluated in terms of flour output, losses and quality of output. The performance of these intermediate processing technologies for shelling and milling operations were then compared with the traditional processing techniques of performing the same operations.

The test result revealed that shelling of maize with tractor wheels incurred the highest percentage of grain damage. A maximum grain output of about 80 kg/hr was obtained with the tractor powered maize sheller compared to 30.90 kg/hr by shelling with tractor wheels and 13.19 kg/hr with the traditional shelling techniques. Shelling with tractor wheels has the lowest shelling efficiency of about 73.76 % when compared with the other shelling methods. The difference of shelling with intermediate technologies and traditional techniques show statically significant differences on grain damage, grain output and shelling efficiency at the 0.05 level.

Greater flour output from sorghum was obtained with the milling technologies than with the traditional milling technique. Higher loss of sorghum flour resulted with the use of traditional milling technique than with the other two milling technologies. Thus, the difference in the milling methods had a statically significant effect on flour output and flour loss. The degree of fineness of sorghum flour particles obtained using the milling technologies were greater than that from the traditional milling technique. The difference in the milling methods have significant effect on the degree of fineness of flour for particle size greater than 1000 micrometers and less than 150 micrometers at the 0.05 level.

Introduction

The concept of intermediate technology was presented by Shumacher (1973) as an alternative course for development of poor people, which enable them to work themselves out of poverty. He described it simply as a “middle way” between traditional and modern technology. It is therefore obvious that the concept of intermediate technology will enable rural people to become more productive in their activities, self-sufficient, sustain income generation and create surpluses, which can be reinvested in their families, businesses and communities.

The processes of separating food grain from the pod (shelling) can be a great loss if performed incorrectly. The most widespread methods of shelling maize are such traditional methods as pricking the grain off the cob with thumbs, rubbing two cobs together (holding one in each hand), or beating the cobs in a sack with a stick or rubbing the cobs across a rock. Simple shelling devices have been invented which can be easily made locally. One of these is a hand held wooden sheller. A number of maize shellers for manual operation, suitable for small-scale producers are manufactured commercially and industrial-scale producers make use of a wide range of engine-operated machines. Trampling by animals, tractor wheels or foot during shelling operations is reported to cause heavy losses, since a percentage of the grain is crushed. Also, when shelling is done on an earth floor, dirt and other impurities can be mixed with the grain (FAO, 1989).

Traditionally, sorghum is usually ground to produce a meal. Pounding with a pestle and mortar is a widely used traditional method, along with grinding slowly between two stones. Hammer mills powered by petrol or diesel engines have been installed in many trading centers. In some areas, such as Botswana and Nigeria, sorghum hulling equipment has been installed in rural areas to supplement the hammer mills. These are mainly custom operations where farmers bring their clean grain for polishing and grinding for a fee. A small number of commercial sorghum processing mills are active in Sudan. Unfortunately, economic difficulties limit the increase in sorghum industrialization. Industrial technologies for milling sorghum are yet not well developed. Not all sorghum varieties can be used successfully in industrial processing (FAO, 1989).

Vergelegen, which was the target community for this study, is a rural community in the Northern Province of South Africa and is notable for cereal production. Cereal crops such as maize and sorghum are central to the nutrition of rural subsistence areas of the Northern Province of South Africa. The seeds of these crops are used by the rural communities in South Africa for making meals, porridges, beverages and cakes. In spite of the food and nutritional importance of these crops to human diet, it's processing (shelling and milling) has been and remains a serious problem to the

Parameter	Specification
Model of tractor used	FORD 6600
Power source	Diesel
Method	The maize sheller is powered by tractor
Speed of sheller	1,048 rpm
Speed of drive	406 rpm
Dia. of drive pulley	12 cm
Dia. of Sheller pulley	31 cm
Maize variety	CG. 4141
Fuel consumption	90 liters / 200 bags
Grain moisture content	16 % (wet basis)

Table 1 Description and specification of the maize sheller

Parameters	Specifications
Gender (operator)	Female
Method of shelling	Hand
Weight of operator	56 kg
Height of operator	154 cm
Age of operator	54 years

Table 2 Description and specification of traditional maize shelling operator

Parameters	Specifications
Model of tractor	FORD 6610
Power source	Diesel
Method	Shelling with tractor wheels

Table 3 Description and specification of the maize shelling with tractor wheels

Parameters	Specifications
Power source	Diesel
Input power	24 HP
Engine type	2 cylinder lister engine
Speed of mill	2,538 rpm
Speed of drive	2,000 rpm
Dia. of mill pulley	13 cm
Dia. of drive pulley	16.5 cm
Fuel consumption	20 liters / 4 bags of maize

Table 4 Description and specification of milling machine 1 (Mill 1)

Parameters	Specifications
Power source	Electrical
Motor	Single phase; 2.2 kW, 12 Amp, 220 V
Speed of mill	1,806 rpm
Speed of drive	1,693 rpm
Dia. of mill pulley	15 cm
Dia. of drive pulley	16 cm
Electricity consumption	R100 / month for 108 kWh by coupon

Table 5 Description and specification of milling machine 2 (Mill 2)

Parameters	Specifications
Gender	Female
Method	Grinding with stone
Weight of operator	57 kg
Height of operator	150 cm
Weight of grinding stone	3.9 kg
Age of operator	70 years

Table 6 Description and specification of traditional milling of sorghum

farmers. However, the processing techniques for these crops are predominantly by traditional methods, which are unproductive, laborious, time wasting, unhealthy and often result in great losses of crops. At Vegelegen, shelling of maize is achieved by pricking by hand, rubbing with stone, beating with sticks, running tractor wheels over heaps of maize, and with a tractor powered maize sheller. Also, milling of sorghum is by grinding with stones on the floor and with electrical and diesel powered machines (Ndirika, 2000).

It is a common view that intermediate agricultural processing technologies, if introduced in the rural communities, would improve the economy and productivity of the rural fold. But over the years few intermediate processing agricultural processing technologies were introduced for processing cereal crops in rural communities in the Northern province of South Africa. However, the performance of these technologies by farmers/households has not been very satisfactory. Ndirika and Buys (2002) recommended in their studies that the performance of the available processing technologies be identified to determine the appropriateness of the technologies as compared to the performance with the traditional processing techniques.

It is, therefore, necessary to evaluate the performance of the intermediate agricultural processing technologies for maize shelling and sorghum milling and compare their performance respectively with traditional techniques of performing the same operations in the target community.

The specific objectives of the study were as follows:

- To evaluate the performance of maize shelling and sorghum milling technologies available in the community.
- To compare the performance of maize shelling and sorghum milling technologies respectively with traditional shelling and milling techniques available in the community.

Materials and Methods

Description of the Intermediate Technologies and Traditional Techniques for Maize Shelling and Sorghum Milling

The intermediate technologies and traditional techniques used for maize shelling and sorghum milling during the performance evaluation are presented in **Figures 1-5**, while the descriptions and specifications of these technologies and traditional techniques are presented in **Tables 1-6**.

Performance Evaluation

The varieties of maize and sorghum used during the performance evaluation were CG.4141 (Zea Mays L.) and sorghum bicolor (L.) Moench respectively. The moisture contents of maize and sorghum grains during the experiment were 16 % and 11 % respectively. Experiments were conducted on the existing intermediate technologies such as tractor powered maize sheller, shelling with tractor wheels and sorghum milling machines (Mills 1 and 2) and traditional processing techniques for maize shelling and sorghum milling. The following parameters were measured and evaluated during the experiments as recommended by ILO (1984) and Ndirika (1994).

Shelling efficiency (SE, %) = $100 - (Q_u / Q_T) \times 100$ ....(1)

Grain output (GO, kg/hr) = Q_s / T ....(2)

Grain damage (GD, %) = $Q_b / Q_T \times 100$ ....(3)

Flour output (FO, kg/hr) = Q_{fo} / T ....(4)

Flour losses (FL, %) = $(Q_T - Q_{fo}) / Q_T \times 100$ ....(5)

Flour quality (% of particles in category): Determined by the degree of fineness of flour particles.

where,

Q_u = quantity of unshelled grain in sample (g)

Q_T = total grain in sample (g)

Q_s = quantity of shelled grains (g)

Q_b = quantity of broken grains in sample (g)

Q_{fo} = quantity of flour milled from sample (g)

T = time taken to complete activity (hr)

It is important to note that there was no sieving during the milling operations in both milling technologies. All the grain samples were milled to flour.

Instrumentation and Measurement

A Mettler balance with 0.01 g precision was used for all weight measurements. A stopwatch was used for all time measurements and a meter rule was used for all length measurements. The grain moisture

Fig. 1 Maize shelling powered by tractor

Fig. 2 Trad. shelling of maize

Fig. 3 Maize shelling with tractor wheels

content was determined by oven dry method at a temperature of 130 degrees Celsius for 18 hours (ASAE, 1972). The degree of fineness (measure of quality) of the sorghum flour from different milling methods were determined using the TASP2 texture analyzer.

Data Analysis

The data from the experimental evaluation of the intermediate technologies and the traditional techniques were analyzed using the SAS Version 6, and Excel statistical packages. Descriptive statistical tools such as tables and bar charts as recommended by Trochim (1999), were used to describe the basic features of the data in the study. Also, inferential statistical tools such as the Generalized Linear Model (GLM) which include: t-test, analysis of variance (ANOVA), chi-square test were used to compare the observed differences between intermediate technologies and the traditional processing techniques.

Results

Shelling Operation

Table 7 shows that the percentage of grain damaged is higher during maize shelling with tractor wheels (15.20 %) than with the maize sheller (1.55 %) and (0 %) with traditional shelling of maize. This shows that shelling method affect grain damage.

Table 7 Effect of shelling methods for maize on grain damage, grain output and shelling efficiency

Parameters	Maize sheller (Av. value)	Shelling with tractor wheels (Av. value)	Trad. shelling (Av. value)	Significant difference (Prob. level)
Grain damage, %	1.55	15.20	0	0.0001*
Grain output, kg/h	80	30.90	13.19	0.0001*
Efficiency, %	93.10	73.76	95.50	0.0001*

* Highly significant

Also, the grain output from the maize sheller (80 kg/h) is greater than shelling with tractor wheels (30.90 kg/h) and traditional shelling (13.19 kg/h). It is also noted that the shelling efficiency with the traditional shelling method (95.50 %) is higher than shelling with maize sheller (93.10 %) which may be due to no grain damage and less losses in the traditional method. Shelling efficiency with the tractor wheel is 73.76 %. The result shows that the effects of different methods of shelling maize (maize sheller, shelling with tractor wheels, and traditional shelling by hand) on grain damage, grain output and shelling efficiency are all highly significant at 0.05 level.

Milling Operation

The average values of output of sorghum flour from mill 1 (210.56 kg/h) was greater than from mill 2 (50 kg/h), and the traditional mill (4 kg/h) as shown in **Fig. 6**. However, the effect of the traditional mill, mill 1 and mill 2 on the output of sorghum flour was highly significant at 0.05 level (**Table 8**).

Degree of Fineness of Flour Particles

From **Table 9** it is clear that the percentage of fine flour particles (<150 micrometers) from sorghum in mill 1 (56.47 %) and mill 2 (13.12 %) are greater than the values obtained with the traditional milling method (10.75 %). Also, the coarse particles (>1000 micrometers) obtained from sorghum meal with the traditional milling method (36.26 %) is greater than the values obtained with mill 1 (0.23 %) and mill 2 (12.98 %). The different milling methods for sorghum have significant effect on the degree of fineness of the meal for particle sizes greater than 1000 micrometer and particle sizes less than 150 micrometer at the 0.05 level.

Flour Losses

The losses of sorghum flour with the use of the traditional method (28.57 %) are greater than with mill 1 (12 %) and mill 2 (17 %) as shown in **Fig. 7**. This may be due to the effect of wind, which often tends to blow the flour away while some sticks to the surface of the larger grinding stone. The different milling methods have significant effect on flour losses from sorghum flour at the 0.05 level (**Table 8**).

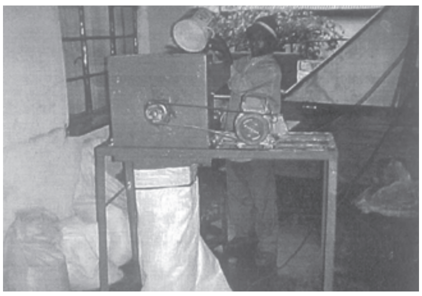


Fig. 4 Milling machine

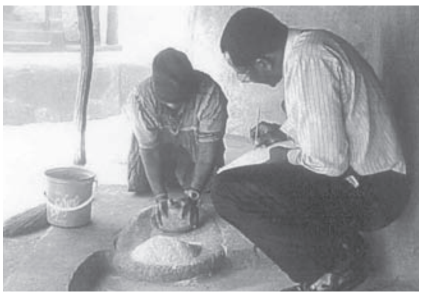


Fig. 5 Trad. milling of sorghum

Conclusions

The following conclusions can be drawn from the results.

• The traditional techniques for processing maize and sorghum result in poor quality, low of output, time wasting and drudgery. Shelling with tractor wheel is inappropriate as this results in high grain damage. The intermediate technologies for shelling and milling are appropriate in terms of improvement in quantity and quality of output, reduction of drudgery and time of operation.

Table 8 Significant difference of effects of sorghum milling methods on flour output and losses

Parameter	Values outputs and losses	Significant difference (Prob. level)
Flour output, kg/h (mill 1, mill 2 and trad. mill)	(210.56, 50, 4)	0.0001*
Flour losses, kg/h (mill 1, mill 2 and trad. mill)	(12, 17, 28.57)	0.0001*

* Highly significant

Table 9 Effect of different milling methods on flour particle sizes sorghum

Parameter	Mill 1	Mill 2	Trad. mill	Significant difference (Prob. level)
Particle > 1000 mm (%)	0.23	12.98	36.26	0.0001*
Particle < 150 mm (%)	56.47	13.12	10.75	0.0001*

* Highly significant

• The milling machine 2 (mill 2) appears to be appropriate for milling activities in the community due to its small size and low cost. Most of the rural households have limited cash to purchase intermediate technologies. This makes the adoption of such technologies difficult. It is also recommended that low cost alternative intermediate technologies such as manually operated maize shellers and milling devices be introduced in the community.

• The difference between shelling with intermediate technologies and traditional techniques has significant effects on grain damage, grain output and shelling efficiency at the 0.05 level.

• The difference between the milling methods has significant effect on flour output and flour losses. Also, the difference between the milling methods has significant effect on the degree of fineness of flour for particle size greater than 1000 micrometers and less than 150 micrometers at the 0.05 level.

REFERNCES

ASAE, 1972. Moisture Measurement-Grain and Seeds. American Society of Agricultural Engineers Standards. ASAE S 352, 1-384.

FAO, 1989. Production Yearbook. Food and Agriculture Organization of the United Nations Rome (FAO).

ILO, 1984. Assessment of Technologies for Rural Women's Activities and Considerations for Improvement of Traditional Methods: Improved Village Technology for Women Activities: A Manual for West Africa. International Office Geneva. International Labor Organization Publications (ILO), pp. 18

Ndirika V. I. O., 1994. Development and Performance Evaluation of A Millet Thresher. Journal of Agricultural Engineering and Technology, 2: 80-89.

Ndirika V. I. O., 2000. Impact Assessment of Intermediate Agricultural Processing Technologies for Cereal Crops: A Case Study of Vergelegen Community Rural Household in the Northern Province of South Africa. Post-Doctoral Research Project Report. Institute for Technological Innovation, Faculty of Engineering, University of Pretoria, South Africa, pp. 92.

Ndirika, V. I. O. and Buys, A. J., 2002. Assessing the Extent of and Constraints to Adoption of Intermediate Agricultural Processing Technologies for Cereal Crops in a Traditional Farming Community of South Africa. International Journal of Agricultural Mechanization in Asia, Africa and Latin America (Accepted for publication). pp. 25

Shumacher, E. F., 1973. Small Is Beautiful: Study of Economics as if People Mattered. ABACUS Edition. Blond and Biggs Publishers, Great Britain, 180-255

Trochim, W. M. K., 1999. The Research Methods Knowledge Base, Cornell University. Custom Publishing, New York, 14853, 108-284.

■■

Fig. 6 Flour output from mill 1, mill 2, and trad. mill

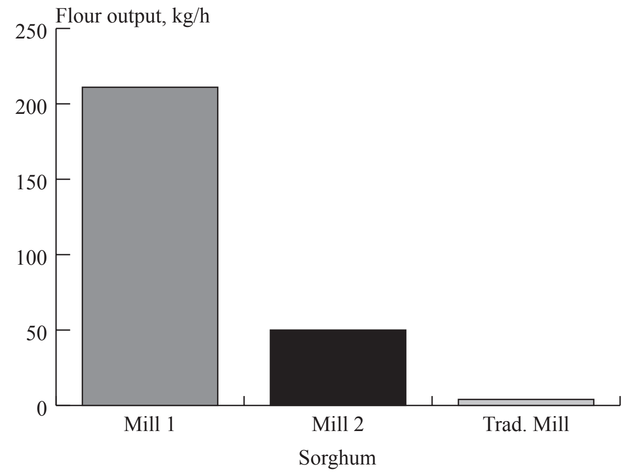
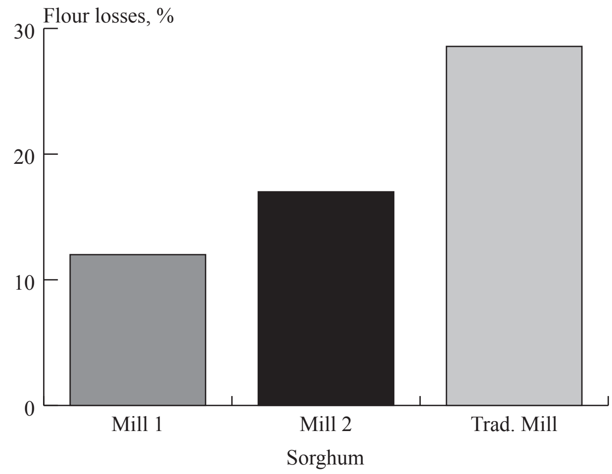


Fig. 7 Flour losses from mill 1, mill 2, and trad. mill



Computer-Aided Design of Extended Octagonal Ring Transducer for Agricultural Implements

by

H. Raheman
Associate Professor
Agricultural and Food Engineering Department,
Indian Institute of Technology,
Kharagpur-721 302
INDIA
hifjur@agfe.iitkgp.ernet.in

R. K. Sahu
Research Scholar
Agricultural and Food Engineering Department,
Indian Institute of Technology,
Kharagpur-721 302
INDIA
rohitkumarsahu@yahoo.co.in

Abstract

The extended octagonal ring transducer is used for suitable measurement of horizontal and vertical forces simultaneously acting on tillage implements in the soil bin as well as in the field. For measurement of any force, the design parameters of the transducer such as center to center distance (2L), width (b), and thickness (t) are to be calculated at different L/r and b/r ratios with various assumed mean ring radii (r) values keeping in mind that thin ring theory is satisfied as well as the elastic limit of the material of construction is not exceeded. Many calculations are required to obtain the best possible transducer, which is time consuming and laborious. To overcome these difficulties, a computer program was written in Visual Basic to determine the suitable dimensions of the extended octagonal ring transducer. The developed program provides intuitive user interface by linking material specifications, strain gauge specifications and transducer dimensions for any horizontal and vertical force. After entering material and strain gauge specifications, simulation was done at various L/r and b/r ratios for different 'r' values for measuring horizontal and vertical forces up to 1 kN. Based on space availability for mounting, the detail dimensions of the transducer were chosen as 2L = 150 mm, r = 38 mm, b = 51 mm and t = 4.5 mm and the sensitivity was predicted to be 0.114 mV/kg and 0.094 mV/kg for horizontal and vertical forces respectively. Based on the above dimensions, an extended octagonal ring transducer was fabricated and then calibrated for measurement of horizontal and vertical forces. The sensitivity from calibration of the transducer was found to be 0.120 mV/kg with R^2 = 0.99 and 0.092 mV/kg with R^2 = 0.99 for horizontal and vertical forces respectively. These high coefficients of determination together with low difference between predicted and actually observed sensitivities validated the developed program for designing the extended octagonal ring transducer.

Introduction

Force transducers are required for measurement of forces acting on tillage implements both in the laboratory soil bin as well as in the field. Where the soil failure is symmetrical, the force system consists of two mutually perpendicular force components; i.e. a horizontal force (H) and a vertical force (V). Because of symmetric soil failure the lateral force (S) becomes zero. Force measurement, by suspending the soil engaging implement from a series of single dynamometers, has been used extensively but there is little detailed information about the comparison of such systems (Rogers and Tanner, 1955; Payne, 1956; O'Callaghan and Farelly, 1964). This single dynamometer may be ring type or octagonal type and the measurement of orthogonal forces has been discussed by a number of scientists (Lowen et al. 1951; Lowen and Cook, 1956; Cook and Robinowicz, 1963; Godwin, 1975, O' Dogherty, 1975; Godwin, 1982 and Thakur and Godwin, 1988). An alternative technique to the multi-dynamometer system is the extended octagonal ring transducer and has been used by various researchers for measurement of orthogonal forces and moments acting in agricultural implements (Godwin, 1975; Thakur and Godwin, 1988; Godwin et al., 1993; O'Dogherty, 1996 and Watyotha and Salokhe, 2001).

Although a number of dynamometers have been used, there has been no account of a rational design procedure, which allows researchers to design an appropriate transducer for their particular application. O'Dogherty (1996) developed a procedure for designing the extended octagonal ring transducer, but, for measuring a particular force, different sizes of transducers can be used. Many calculations are needed to obtain the best possible transducer. Hence, a computer program was written in Visual Basic to design the extended octagonal ring transducer for measurement of forces acting on agricultural implements because it is an excellent tool for developing flexible and user-friendly software for various applications. It is considered as a new approach for development of a program for designing the transducers for agricultural applications.

Transducer Design Considerations

Transducers for measurement of forces and moments for agricultural applications may be ring type, simple octagonal type or extended octagonal ring type. The essential principle of operation for all these transducers is that when orthogonal forces are applied to any of theses transducers, there are stress nodes (i.e. positions where there is no contribution to the stress from the other force component), which can be used as a basis for independent force component measurement and the resulting moment. The accuracy of location of the stress nodes and subsequent positioning of the strain gauges are critical in producing a transducer with low cross sensitivity between the force component channels.

Thin Ring Formulae

The bending moments of a thin ring (**Fig. 1**) due to diametrical forces, F, and Tangential forces, P, at an angle of to the direction of force, F, are given by

$M_\theta = 0.5Fr(\sin\theta - 2/\pi)$, and ....(1)

$M_\theta = 0.5Pr\cos\theta$. ....(2)

In the above it is assumed that the top and bottom of the ring are to be restrained from rotation and clockwise moments are positive. The bending moment and, therefore, stress and strain at the surface of the ring section are zero for the forces F and P at angles, θ, of 39.5 and 90º, respectively. The angle at which zero stress and strain occur are known as nodal angles, ø. Therefore, if strain gauges are mounted in these positions and connected into the Wheatstone bridge configurations shown in **Fig. 1**, the gauges at an angle of 39.5º will measure the force, P, independently of F and those at 90º will measure the force, F, independently of P. This is the essential principle of a biaxial force dynamometer based on a ring which exhibits no interaction between the two orthogonal forces.

From the elementary theory, using Eqns. (1) and (2) for the bending moments, the strains at the surfaces of a ring of rectangular section (given by $\varepsilon = 6M/bt^2$) for the two angles 90º and 39.5º can be given as

$\varepsilon_{90^\circ} = 1.09Fr/Ebt^2$, and ....(3)

$\varepsilon_{39.5^\circ} = 2.31Pr/Ebt^2$. ....(4)

The sensitivity of a fully active strain gauge bridge is given by

$\Delta V/V = k\varepsilon$. ....(5)

The bridge sensitivity can be calculated by substitution of strains of Eqns. (3) and (4) in Eqn. (5). The sensitivities are usually expressed in terms of bridge output voltage per unit force applied. The deflections and of the ring under the action of forces F and P can be obtained by using Castigliano's theorem and are

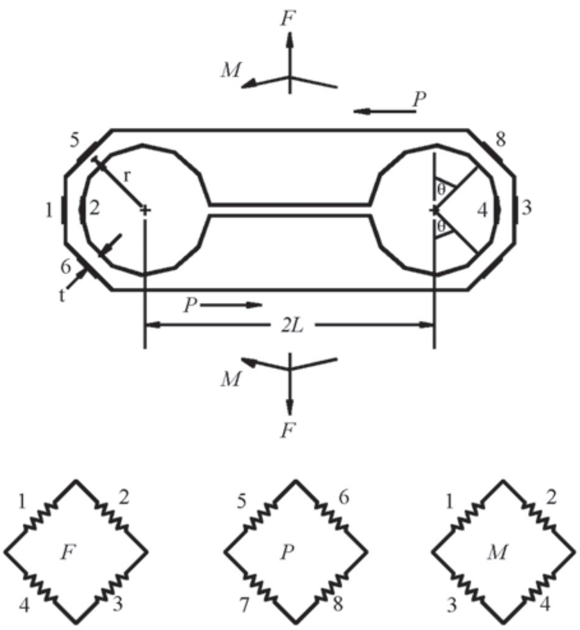


Fig. 1 Extended octagonal ring transducer with strain gauges for measurement of forces and moments

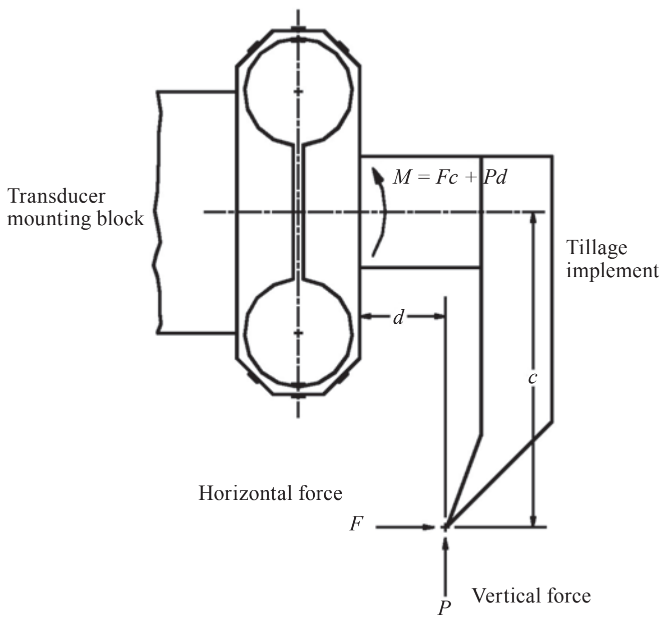


Fig. 2 Forces acting on a soil tillage implement attached to the extended octagonal ring transducer and their resulting moments

given by

$\delta_F = 1.79Fr^3/Ebt^3$, and ....(6)

$\delta_P = 9.42Pr^3/Ebt^3$. ....(7)

Extended octagonal ring transducer

O'Dogherty (1996) made an analysis using Castigliano's theorem for an extended thin circular ring under the action of forces F and P and also under the action of applied moments, M, in the plane of the dynamometer (**Fig. 1**) assuming that the central sections were very thick in relation to ring thickness. The solution for an applied moment is necessary because in many practical applications the point of action of forces F (draft) and P (vertical force) acting on a soil tillage implement is such as to apply a moment of significance magnitude to the dynamometer as shown in **Fig. 2**. It was found that for the forces F and P, the bending moment expressions were the same as given in Eqns. (1) and (2), assuming that the strain energy of the central sections was negligible. This agrees with the expressions given by Hoag and Yoeger (1974) for an extended ring.

O'Dogherty (1996), using Castigliano's theorem derived an expression for the bending moment at an angle to the direction of the force F in the extended ring when acted upon by the moment, M_θ, is

$$M_\theta = \frac{0.5M\{(K+2/\pi)\sin\theta - 2K/\pi - 0.5\}}{K^2+4K/\pi+0.5} \quad \text{.........................(8)}$$

where K = L/r.

When two orthogonal forces act on a tillage implement as shown in **Fig. 2**, the applied moment is given by

M = Fc + Pd. ....(9)

To measure the moment, M, strain gauges are attached to the transducer as shown in **Fig. 1** and arranged in the Wheatstone bridge in the manner shown. At θ = 90º, the bending moment is given by

$$M_{90^\circ} = \frac{0.5M\{(1-2/\pi)K+2/\pi-0.5\}}{K^2+4K/\pi+0.5} \quad \text{.......................(10)}$$

The strain at the ring surfaces in this angular position is given by

$$\varepsilon_{90^\circ} = \frac{3M\{(1-2/\pi)K+2/\pi-0.5\}}{Ebt^2(K^2+4K/\pi+0.5)} \quad \text{........................(11)}$$

This expression agrees with that given by Loewan and Cook (1956). The maximum moments arising from the forces F and P, which occur at θ = 0º and θ = 180º, can be found from expressions given by Godwin et al. (1993) and are as follows:

$(M_{max})_F$=0.5Fr sinø, and..........(12)

$(M_{max})_P$ = 0.5Pr. ....(13)

Semi-empirical equations developed by O'Dogherty (1996) for Maximum strains at θ = 90º or 180º due to force F and P are as follows:

$(\varepsilon_{max})_F = 2.62Fr/Ebt^2$, and..........(14)

$(\varepsilon_{max})_P = 2.17Pr/Ebt^2$. ....(15)

The maximum value of strain at ring surface due to the largest value of the bending moment can be obtained from Eqn. (12) by putting = 90º or 180º.

$$(\varepsilon_{max})_M = \frac{3M(2K/\pi+0.5)}{Ebt^2(K^2+4K/\pi+0.5)} \quad \text{.......................(16)}$$

For all design purposes, taking a factor of safety as 1.35, Eqn. (16) becomes

$$(\varepsilon_{max})_M = \frac{4.05M(2K/\pi+0.5)}{Ebt^2(K^2+4K/\pi+0.5)} \quad \text{.......................(17)}$$

The bending moment will be positive on one half of the ring and negative on the other depending on the sense of the applied moment. The total tensile or compressive stress, which occurs at the ring surface, is given by combining Eqns. (14), (15) and (17).

...................(Equation 18)

By rearranging the Eqn. (18), the minimum value of ring thickness 't' required will be determined for a range of values of K.

...................(Equation 19)

Transducer Design Procedure

It is necessary to select a mean ring radius, r, and thickness, t, so that the elastic limit of the material of construction is not exceeded when designing a dynamometer. In addition, the design must conform to an appropriate value of r/t to satisfy thin ring theory. If L, b and r are chosen, the minimum value of t required can be calculated from Eqn. (19) and hence the value r/t to satisfy the thin ring theory can be checked.

The selection of the mean radius of the ring (r), distance between ring centers (2L), and width (b) of the dynamometer is dependent on the size of agricultural equipment/implement to which it will be attached and space and weight considerations. In order to conform with the assumptions of thin ring theory, the ratio r/t ≥ 5, but considerations of the stress distribution across ring section show that a lower limit of r/t can be accepted; i.e. up to r/t ≥ 3 (Den Hartog, 1961 and Roark, 1965). But, when the ratio r/t be-

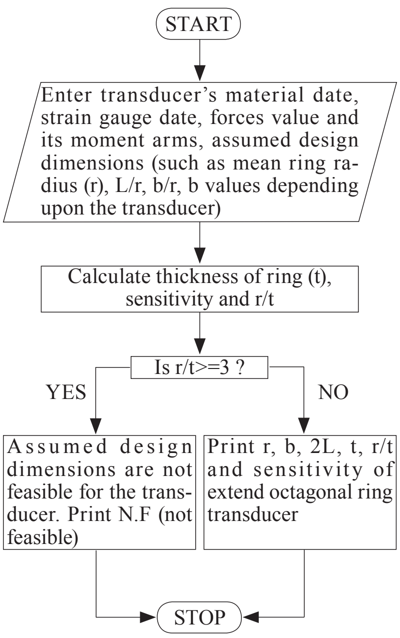


Fig. 3 Flow chart for simulation of extended octagonal ring transducer design program

$$\sigma_{max} = \frac{r\{2.62F+2.17P+4.05M(2K/\pi+0.5)/r(K^2+4K/\pi+0.5)\}}{bt^2} \quad \text{.....................(18)}$$

$$t^2 = \frac{r\{2.62F+2.17P+4.05M(2K/\pi+0.5)/r(K^2+4K/\pi+0.5)\}}{b\sigma_{max}} \quad \text{..........................(19)}$$

Combi-nation	L/r	b/r	Mean ring radius (mm)	Width of ring (mm)	Thickness of ring (mm)	Distance be-tween cen-tres of two rings (mm)	r/t ratio	Sensitivity (mV/kg)	
								Vertical force	Horizontal force
1	2.0	1.35	38	50.9	4.5	150.5	8.4	0.094	0.114
2	2.5	1.35	38	51.3	4.2	190	9.0	0.108	0.130
3	2.0	2.5	38	95	3.3	152	11.6	0.177	0.213
4	3.0	3.0	38	114	2.7	228	14.2	0.265	0.320

Table 1 Different combinations of design parameters of the transducer for 1 kN force

comes less than 3, the values of stress at the curved surfaces of a circular beam begin to depart rapidly from the values applicable to a straight beam (O'Dogherty, 1996).

The ratio b/r has the greatest effect on values of r/t with a 72 % increase over the range 1 to 3, compared with a 35 % increase when the ratio L/r is increased over the same range (O'Dogherty, 1996). Dynamometers designed by various scientists used ratios of L/r and b/r in the range 1.5 to 3 (O'Dogherty, 1975; Godwin, 1975; Godwin, 1982; Godwin et al, 1987; Gebresenbet, 1989; Godwin et al, 1993; Kirisci, 1994 and O'Dogherty, 1996). Experiments show that, at large applied forces, the mean radius of the ring must be increased considerably to maintain a minimum value of r/t = 3. The mean radius can be significantly reduced by increasing the dynamometer dimensions L and b.

Computer Program Development

A flexible, user friendly and comprehensive menu based computer program in Visual Basic language was developed to design extended octagonal ring transducers for measurement of forces acting on agricultural implements. Visual programming provides a set of screens, object buttons, scroll bars and menus. The user can access various object-driven windows to edit or expand data. The developed program provides intuitive user interface by linking material specification, strain gauge specification and transducer dimensions for any horizontal and vertical force. The specifications of material and strain gauge were entered for designing an extended octagonal ring transducer to measure up to 1.0 kN each of the horizontal and vertical forces with moment arms of 500 and 250 mm. Then, simulation was done at various L/r and b/r ratios for different 'r' values with a factor of safety 1.35. The flow chart of the program is shown in **Fig. 3**.

Results

The output of the program gave different combinations of design parameters for measurement of these forces (**Table 1**). This program also helped identify the most suitable dimensions of the transducer when space, weight, r/t ratio and sensitivity were considered. Based on space availability for mounting, the detail dimensions of the transducer were identified as 2L = 150 mm, r = 38 mm, b= 51 mm and t = 4.5 mm and the sensitivity was predicted to be 0.114 mV/kg and 0.094 mV/kg for horizontal and vertical forces respectively.

Based on the above dimensions, an extended octagonal ring transducer was fabricated (**Fig. 4**) and then calibrated for measurement of horizontal and vertical forces (**Fig. 5**). The actual sensitivity of the transducer was found to be 0.120 mV/kg with R^2 = 0.99 and 0.092 mV/kg with R^2 = 0.99 for horizontal and vertical forces respectively. These high coefficients of determination together with low difference between predicted and actually observed sensitivities validated the developed program for designing the extended octagonal ring transducer.

Conclusions

The program for designing the transducer for agricultural engineering application was developed

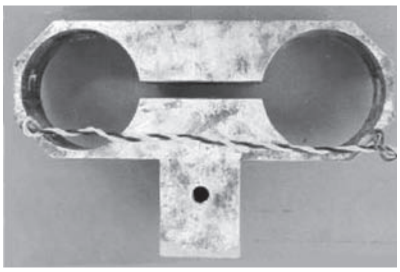


Fig. 4 The extended octagonal ring transducer fabricated based on simulation

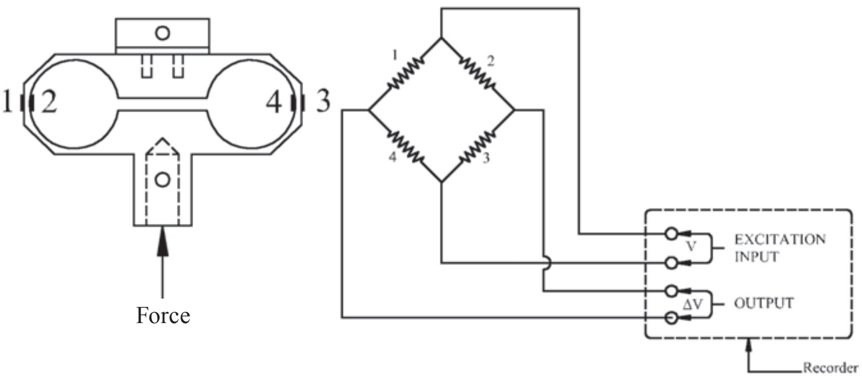


Fig. 5 Transducer and circuit diagram for measurement of forces

in a Visual Programming environment for use in educational and research needs. The intuitive user interface to the model was a visual object oriented window, which allowed the selection of the transducer and its material properties and allowed changes to the force to be measured, the ring diameter, L/r and b/r ratios and initiated computation. This program also helped in deciding the best suitable dimensions of the transducer, taking into consideration the space, weight and maximum sensitivity. For measuring horizontal and vertical forces up to 1 kN, the developed program was run to decide the dimensions of the transducer. Based on the predicted dimensions, an extended octagonal ring transducer was fabricated from mild steel block. The actual and predicted sensitivities of the transducer for horizontal and vertical forces varied within 5 and 2 % respectively. Thus, the developed program in Visual Basic can be used as a tool in determining the dimensions of the extended octagonal ring transducers.

Notation

M: Moment acting on the transducer

M_θ: Bending moment acting at angle of θ to the line of action of diametrical force, F

ε: Strain at ring surface

δ: Deflection of ring along line of action of applied force

σ: Tensile or compressive stress

ø: Nodal angle at which stress due to diametrical force, F

E: Young's modulus of transducer material

V: Strain gauge bridge supply voltage

ΔV: Strain gauge bridge output voltage

k: Strain gauge factor

c: Distance of line of action of diametrical force F from central line of the transducer

d: Distance of line of action of tangetial force P from top surface of the transducer

REFERENCES

Cook, N. H. and Rabinowicz, F. 1963. Physical measurement and analysis. New York. Addison-Wesley.

Den hartog, J. P. 1961. Strength of Materials. New York, Dover Publications.

Gebresenbet, G. 1989. Multicomponent dynamometer for measurement of forces on plough bodies. Journal of Agri. Engg. Res., 42, 85-96.

Godwin, R. J. 1975. An extended octagonal ring transducer for use in tillage studies. Journal of Agri. Engg. Res., 20(4), 347-352.

Godwin, R. J. 1982. Force measurements on tillage implements, Proceedings of the 9th Conference of the International Soil Tillage Research OrganisationYugoslavia, Osijek.

Godwin, R. J., Magalhaes, P. S. C, Miller S. M. and Fry, R. K. 1987. Instrumentation to study the force systems and vertical dynamic behaviour of soil engaging instruments. Journal of Agri. Engg. Res., 36, 301-310.

Godwin, R. J., Reynolds, A. J., O' Dogherty, M. J. and Al-Ghazal, A. A. 1993. A triaxial dynamometer for force and moment measurements on tillage implements. Journal of Agril. Engg. Res., 55, 189-205.

Hoag, D. L. and Yoerger, R. R. 1974. Designing load rings for measurement. Trans. American Soc. Agric. Engg. 17:251-253,261.

Kirisci, V. 1994. A field method for predicting the draught forces of tillage implements. Ph. D. Thesis. Silsoe College, Cranefield University.

Lowen, E. G. and Cook, N. G. 1956. Metal cutting measurements and their interpretation. Proceedings of the Society of Experimental Stress Analysis, 13(3), 57-62.

Lowen, E. G., Marshall, E. R. and Shaw, M. C. 1951. Electric strain gauge tool dynamometers. Proceedings of the Society of Experimental Stress Analysis, 8(2), 1-16.

O'Callaghan, J. R. and Farelly, K. M. 1964. Cleavage of soil by tined implements. J. Agric. Engg. Res. 9(3), 259.

O'Dogherty, M. J. 1975. A dynamometer to measure the forces on a sugarbeet topping knife. Journal Of Agril. Engg. Res., 20(4), 339-345.

O'Dogherty, M. J. 1996. The design of octagonal ring dynamometers. Journal of Agril Engg. Res. 63, 9-18.

Payne, P. C. J.1956. The relationship between the mechanical properties of soil and the performance of simple cultivation implements. Journal of Agric. Engg. Res. 1(1), 23.

Roark, R. J. 1965. Formulae for stress and strain. New York. McGraw Hill.

Rogers, O. J. J. and Tanner, D. W. 1955. Measurements with strain gauges at the N.I.A.E., Part 1. Technical memorandum 106, National Institute of Agricultural Engineering, Silsoe.

Thakur, T. C. and Godwin, R. J. 1988. Design of extended octagonal ring dynamometer for rotary studies. AMA, 19(3), 23-28.

Watyotha, C., and Salokhe, V. M. 2001. Development of a data acquisistion system for measuring the characteristics of real time forces by cage wheels. Journal of Terramechanics. 38, 201-210.

■■

Optimization of Seed Rate of Direct Rice Seeder as Influenced by Machine and Operational Parameters

by

S. S. Sivakumar
Assistant Professor
Department of Farm Machinery,
Agrl. Engg. College and Research Institute,
TNAU, Coimbatore-641 003
INDIA

R. Manian
Professor and Head
Department of Farm Machinery,
Agrl. Engg. College and Research Institute,
TNAU, Coimbatore-641 003
INDIA

K. Kathirvel
Professor
Department of Farm Machinery,
Agrl. Engg. College and Research Institute,
TNAU, Coimbatore-641 003
INDIA

Abstract

In the existing models of the direct rice seeder, the dry/wet seeds are drilled continuously at a higher seed rate than recommended and without desired seed to seed spacing. It is observed that as the seed drum empties the seeding rate is increased steadily and rapidly at the end. Therefore, the uniformity of seed rate is not maintained throughout the operation. This investigation was carried out to study the influence of the machine and operational parameters that included drum shape, diameter of drum, diameter of seed metering hole, number of seed metering holes and forward speed of operation on seed rate of the rice drum seeder in laboratory conditions. The hyperboloid drum shape was optimized with 200 mm drum diameter, nine seed metering holes with 10 mm diameter, and 1.0 km h^{-1} forward speed of operation. The seed discharge rate was optimized by providing baffles, and the effect of filling the seed drums was investigated.

Introduction

Transplanting of rice seedlings being a highly labour-intensive and costly method could be substituted by direct seeding, which could reduce labour hours by more than 20 percent. Direct seeded rice is an age-old practice of paddy cultivation in India, particularly in rain fed areas, where farmers totally eliminate the seedling preparation in nursery and transplanting. Rice is either dry seeded on well-prepared dry/moist soil or wet seeded on puddled soil. The drum seeder is becoming popular for wet seeding because of its lower initial investment, easy operation and low repair and maintenance cost. Several models of drum seeders were developed by IRRI and modified by different organizations/institutions that are manually operated and are highly suitable for fragmented Indian fields.

In all these models the dry/wet seeds are drilled continuously at a higher seed rate than recommended and without desired seed to seed spacing. It is observed that, as the seed drum empties, the seeding rate increases steadily and rapidly at the end. Therefore, the uniformity in seeding rate is not maintained throughout the operation. Hence, a modified drum seeder which provides uniform seed distribution with respect to time will be more useful in maintaining uniform plant population per square metre throughout the field. This creates a condition similar to that of the transplanted crop to have a noticeable improvement in crop growth environment. Also the problem of thinning the crop sown by presently available models of drum seeders could be eliminated.

Review of Literature

Pradhan (1969) demonstrated the successful adoption of direct seeding in lines in puddled rice fields using a seeder. This practice could replace transplanting without any attendant reduction in yield but with reduced cost of operation. Row sown rice showed rapid establishment and greater vegetative growth due to absence of transplantation shock. Sowing of pre-germinated paddy seeds as an alternative to transplanting has gained acceptance over the years. Kandasamy (1987) reported a saving of 298.8 mm of water under direct sown crop, which was 22.1 percent less than the amount used by transplanted crop. Wang and Sun (1990) noticed that duration was shortened by 7-15 days in direct seeded rice compared to transplanted rice. Shekar and Singh (1991) stated that direct seeding of sprouted seeds under puddled condition resulted in significant improvement in yield attributes like number of effective tillers and grain yield. Borlagdan et al (1995) developed a drum seeder at IRRI for sowing pre-germinated seeds on the surface of puddled soil. The seeder was tested with five rice varieties with a varying seed rate of 38 kg ha^{-1} to 80 kg ha^{-1}. The shapes of the drums were cylindrical. The number of tillers per unit area and leaf area index were also more in row sown rice than in broadcast and transplanted rice (Bharathi, 1996).

Materials and Methods

Construction of Test Rig

A test rig was developed for measuring the seed rate of paddy at various forward speeds of operation with different machine parameters. The test rig consisted of a mainframe and variable speed drive. The main frame was a cuboid shaped frame with members at all its edges fabricated with 60 x 38 mm mild steel angle sections. The over all dimension of the unit is 1300 x 670 x 820 mm. At one end of the top frame a 25 mm diameter shaft was mounted through a set of bush bearings for mounting the seed drum. At the other end a variable speed drive operated by a 0.5 kW electric motor was mounted.

The drive to the seed drum-rotating shaft was transmitted through counter shafts and pulley system. A control switch was provided on the main frame for operating the electric motor. The speed obtained from the electric motor was reduced from 1,420 rpm to the required level of 9 to 11 rpm for the seed drum through the variable speed drive mechanism and pulleys mounted on the counter shafts. The test seed drum was mounted on the drum shaft of the test rig. A hopper made of 1.5 mm GI sheet was provided at the bottom of the drum to collect the seeds falling from the drum. The seeds were collected in a container for a known number of revolutions of the seed drum and weighed.

Machine Parameters

The machine parameters that may affect the performance of a drum seeder are drum shape (S), drum diameter (D), diameter of seed metering hole (d), number of seed metering holes (n) and forward speed of operation (v). The influence of the above mentioned parameters on seed rate of a drum seeder was investigated in the laboratory. The levels that affect the performance of a drum seeder for the identified variables selected for the laboratory investigation are discussed below.

a. Drum Shape (S)

The shape of the seed drum is an important factor that affects the flow of the seeds towards the metering holes and the uniformity of flow. The three shapes of seed drums (S) selected are cylindrical, hyperboloid (truncated cone) and cylindrical ellipsoid shape (barrel) as shown in **Fig.1**. In hyperboloid and in cylindrical ellipsoid shapes the longitudinal slopping sides were provided with an inclination of 5 degrees to facilitate the free flow of seeds towards the metering holes for better uniformity.

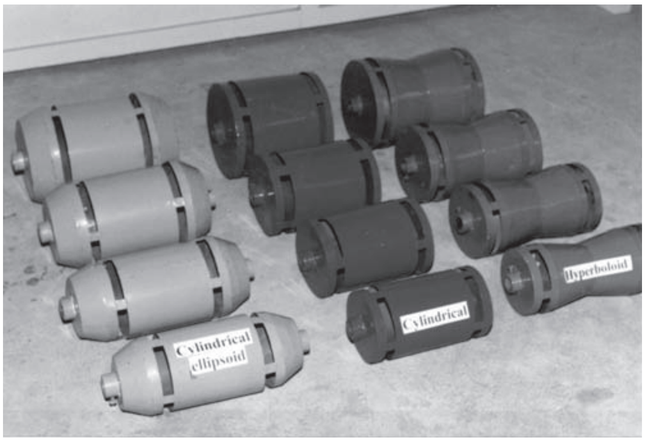


Fig. 1 View of selected seed drum shapes (150, 175, 200 and 250 mm diameter)

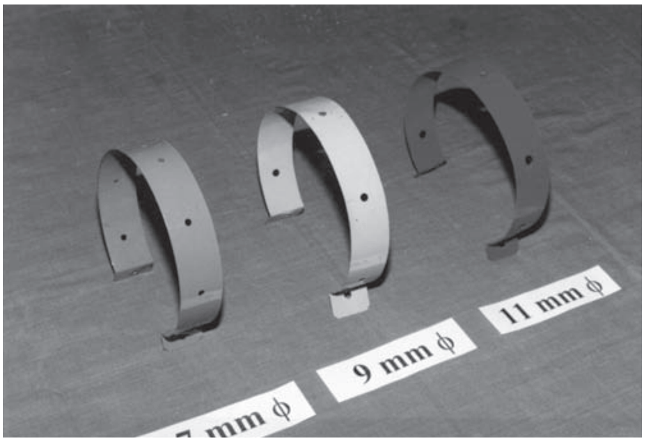


Fig. 2 Strips with varying diameter of seed metering holes

b. Drum Diameter (D)

The drum diameter was considered as a major factor influencing the performance of the seeder in terms of capacity of the seed drum, number of fillings required, and ease of operation. The four levels of drum diameter (D) were selected as 150, 175, 200 and 250 mm for this investigation.

c. Diameter of Seed Metering Hole (d)

The diameter of the seed metering hole has a profound effect on free flow of seeds to obtain the required seed rate for different varieties of paddy. The length, breadth and thickness of the predominant fifteen varieties of paddy in the study area were measured and the length of the paddy seeds of selected varieties varied from 6.9 to 9.8 mm. Therefore, three levels of the diameter of the seed-metering hole (d) selected for this study were 7 mm, 9 mm, and 11mm. The holes were made of 22 gauge galvanized iron sheet circular strips (**Fig. 2**), which can be fixed on the seed drums. Strips of varying diameter were made to fix them on the selected four levels of drum diameter.

d. Number of Seed Metering Holes (n)

The number of seed metering holes coupled with optimum diameter of the holes determined the seed rate. The five levels of number of holes of 5, 6, 7, 8, and 9 were selected after experimentation on the existing TNAU drum seeder.

e. Forward Speed of Operation (v)

The forward speed of operation should be well with in the normal walking speed of the operator in the puddled field for increased comfort and maximum endurance time of the operator pulling the drum seeder. Hence, the three levels of forward speed of operation were 1.0, 1.25 and 1.5 km h^{-1}.

Fabrication of Seed Drums

The three shapes of the drum were cylindrical, hyperboloid and cylindrical ellipsoid and the four diameters were 150, 175, 200 and 250 mm. The drums were made of 22 gauge GI sheet material with provision to mount strips of GI sheets having 5, 6, 7, 8 and 9 holes with varying hole diameters of 7, 9 and 11 mm. For each size of drum, the desired diameter of seed metering hole with the selected number of holes could be obtained by mounting the required strip on the drum. The drums were provided with 25 mm diameter mild steel bushes on both the ends to facilitate the mounting on the drive shaft of the test rig.

Optimization of Machine Parameters

The developed test rig was used to evaluate the seed drums with the selected levels of variables in order to achieve the desired seed rate of paddy. A drum with the seed-metering hole of specified diameter and number of holes was mounted on the test rig and seed were placed in the drum to two-thirds of its volume and the drum was rotated at a speed that simulated a selected forward speed. The seeds falling from the drum were collected for 50 revolutions of the drum and weighed on an electronic balance to a precision of 0.01 g. The results were recorded. Each test was replicated three times. Similar testing procedure was adopted for all the three shapes of the drums and for all combinations of number and diameter of holes and forward speeds. The seed rates were calculated and recorded from the values of weight of seeds collected on each trial.

Statistical Analysis and Mathematical Modeling

The laboratory results were statistically analyzed with the Statistical Packages for Social Studies (SPSS) for assessing the effect of the variables (number of seed metering holes, X_1, diameter of seed metering hole, X_2, forward speed of operation, X_3, and the diameter of drum, X_4) on the drum shape for each rate, Y. Mathematical models were proposed for optimization. From the results of the analysis, the best combination of the selected parameters

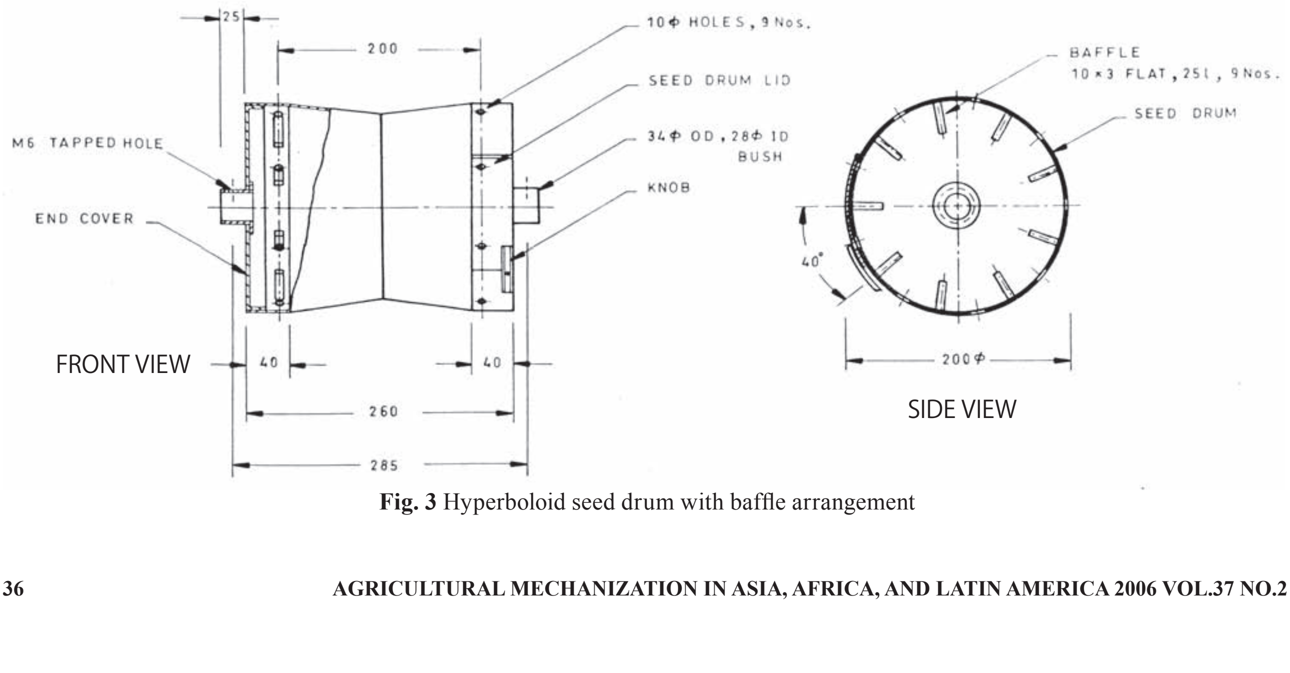


Fig. 3 Hyperboloid seed drum with baffle arrangement

was chosen to get the recommended seed rate of 80 kg ha^{-1}.

Percent Variation in Seed Discharge

A prototype drum with optimized parameters was fabricated from the results of the analysis of the laboratory studies. The optimized drum was further tested in the test rig with two levels of filling (one-half and two-thirds volume) to analyze the effect of filling on percent variation in seed discharge. The seed were collected at one-minute interval until the drum was empty. The per-cent variation of the weight of seed discharged at each minute interval was computed using the following expression.

Percent variation in seed discharge

$$= \frac{(W_a - W_r)}{W_r} \times 100$$

where,

W_a = Actual weight of seeds collected from the drum at each minute, g

W_r = Weight of seeds required to be dropped per minute to achieve the recommended seed rate, g

The most uniform plant population would be obtained when the per-cent variation in seed discharge was minimum.

Effect of Baffles on Percent Variation in Seed Discharge

Baffles of varying configuration were provided between the holes inside the drum to reduce the bridging effect and achieve more uniform flow of seeds from the drum (**Fig. 3**). The baffles were fixed between the holes to disturb the bridging effect and to create agitation of seeds as the seed drum rotated. After incorporation of baffles, the test rig was used to determine the uniformity of seed distribution.

Development of Prototype Drum Seeder

An optimized model of the drum seeder for manual operation was fabricated for evaluation. The unit consisted of a seed drum, main shaft, ground wheel, floats, furrow openers and handle. The seed drum was hyperboloid shape (truncated cone) with 200 mm diameter having 12 mm flat spikes of 25 mm length kept parallel to the axis of rotation. The slopes of the cone facilitate the free flow of seeds towards the metering holes. Nine seed metering holes of 10 mm diameter were provided along the circumference of the drum at both the ends at a row-to-row spacing of 200 mm. The main shaft of the drum seeder consisted of a 25 mm mild steel pipe 1.5 mm thick. For better traction 12

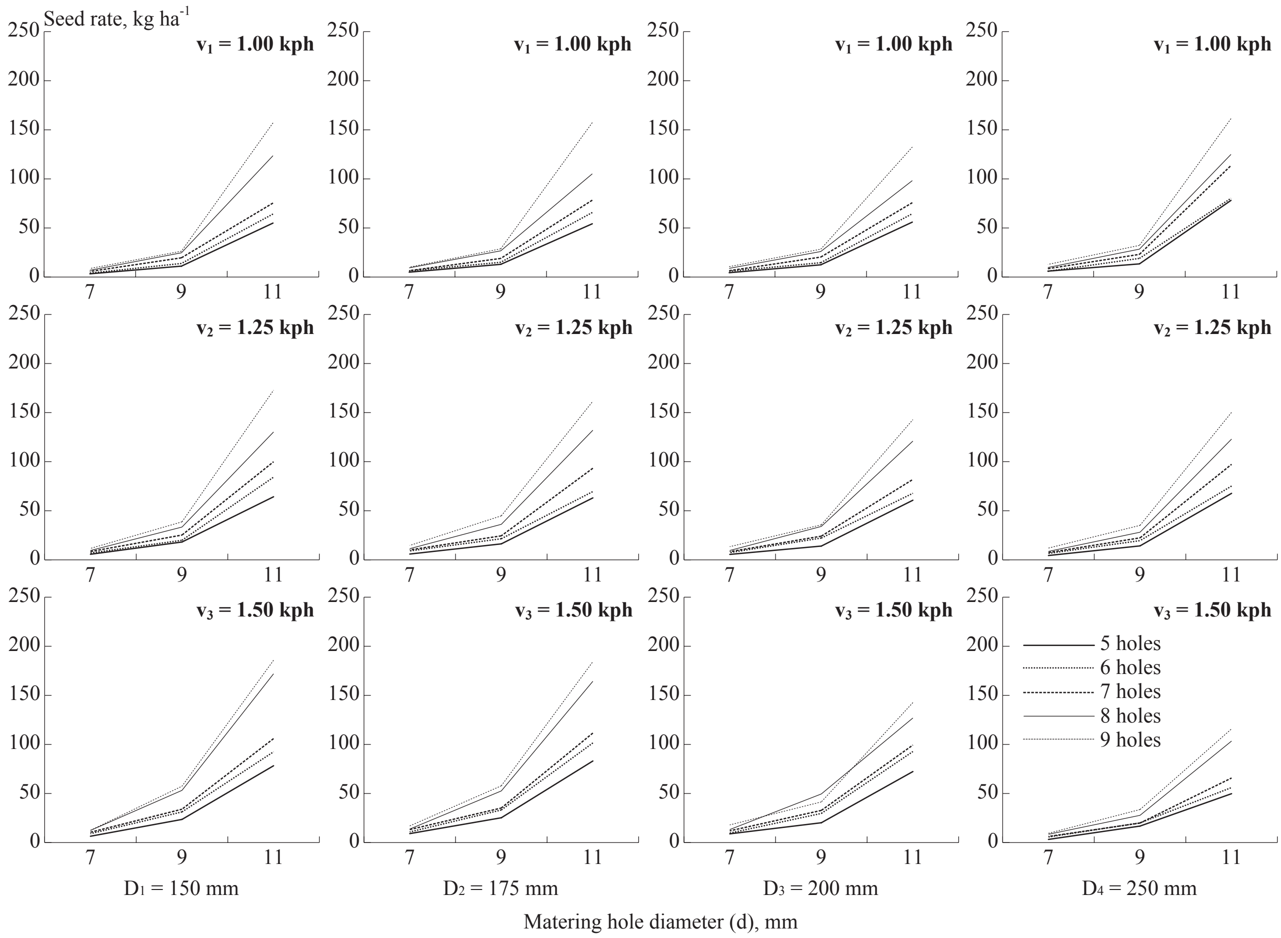


Fig. 4 Effect of hole diameter on seed rate at selected forward speed of operation for cylindrical drum (S_1)

lugs made of 22 gauge galvanized iron sheet were welded on the inner periphery of the wheel. Two floats were provided on either side to restrict the sinkage and to facilitate easy pulling of the unit.

Furrow openers of IRRI design were provided to make the seeds fall in an opened furrow and avoid the scattering of seeds. The position of the opener was set to have a marked furrow on the soil surface. The depth of furrow could be adjusted by adjusting the position of a bolt on the travel hole of the furrow opener. The handle of the drum seeder was made of 18 mm mild steel pipe and attached to the main shaft by 25 mm mild steel pipe bushes. The height of the handle from the ground level can be adjusted using the holes provided depending on the height of the operator.

Results and Discussion

Optimization of Machine Parameters

The test rig was used and the seed drums evaluated to optimize the variables for the desired seed rate.

Cylindrical Seed Drum

The effect of diameter of seed metering holes on seed rate at selected forward speeds of operation for different drum diameters in the cylindrical drum is presented in **Fig. 4**. Increase in the diameter of the seed metering holes (d) from 7 to 9 mm resulted in a uniform and gradual increase in seed rate for all the selected number of seed metering holes (n). Further increase in diameter from 9 to 11 mm resulted in a steep increase of seed rate. The increase of forward speed (v) from 1.0 to 1.5 km h^{-1} had little effect on seed rate for all combinations of hole diameter and number of holes.

In all the cases, the desired seed rate of 80 kg ha^{-1} was obtained for the hole diameter in the range of 10 to 11 mm and only at 7, 8 and 9 number of holes. These values are good only for drum diameters of 150, 175 and 250 mm. For the drum diameter of 200 mm, the desired seed rate range was obtained only with 8 and 9 number of seed metering holes. The increase in drum diameter from 175 to 200 mm (D_2 to D_3) resulted in lowering the seed rate for all combinations of diameter of seed metering holes and number of seed metering holes. However further increase in drum diameter to 250 mm resulted in an increase in seed rate except at 1.5 km h^{-1}.

Hyperboloid Seed Drum

The effect of diameter of seed me-

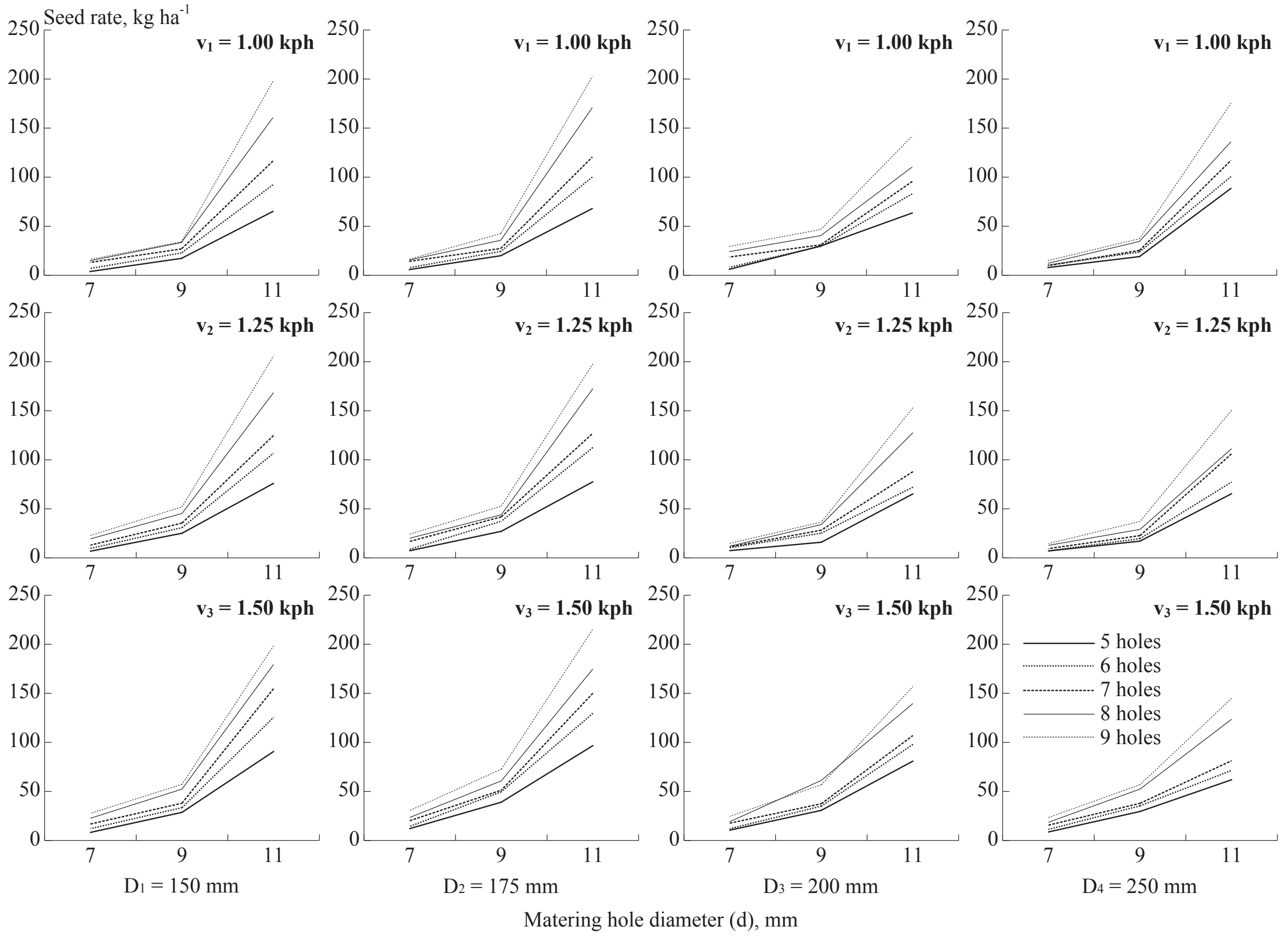


Fig. 5 Effect of hole diameter on seed rate at selected forward speed of operation for hyperboloid seed drum (S_2)

tering holes on seed rate at selected forward speeds of operation for different drum diameters in the hyperboloid drum is presented in **Fig. 5**. The trend of seed rate exhibited is similar to that of cylindrical drum for all combinations of diameter of seed metering holes and number of seed metering holes at different forward speeds of operation and drum diameters except for 200 mm diameter seed drum. The variation in seed rate with increase in diameter of seed metering holes is less with 200 mm seed drum diameter and number of seed metering holes. When compared to cylindrical seed drum the forward speed had more effect on hyperboloid seed drum.

Cylindrical Ellipsoid Seed Drum

The effect of diameter of seed metering holes on seed rate at selected forward speeds of operation for different drum diameters in the cylindrical ellipsoid drum are presented in **Fig. 6**. The behaviour of seed rate in the cylindrical ellipsoid drum followed the same trend as that of cylindrical and hyperboloid drums for all combinations of diameter of seed metering holes and number of seed metering holes at different forward speeds of operation and drum diameters. Thus, it can be inferred that a higher seed rate is possible with the seed metering hole diameter of 10 to 11 mm and 8 and 9 numbers of seed metering holes for selected drums for all forward speeds of operation and drum diameters. As the effect of forward speed of operation on seed rate is non-significant, the optimization was done based on the practical difficulty of walking in a puddled field and pulling the drum seeder. The forward speed of operation was fixed at a level of 1.0 km h^{-1} which is in close agreement with the results of the studies conducted by other researchers.

Effect of Drum Diameter

The desired seed rate could be obtained in all the drum shapes at 10 to 11 mm diameter of seed metering holes with 8 and 9 number of holes for all the four levels of drum diameter. All the three drum shapes having 8 and 9 number of holes at 200 mm drum diameter resulted in non-significant variation of seed rate, where, as at other diameters, the variation in the seed rate was significant for all drum shapes. The non-significant variation in seed rate of 200 mm diameter in all the drum shapes might be attributed to the combined effect of seed drum curvature and rotational speed which influences the flow path trajectory of paddy in addition to the

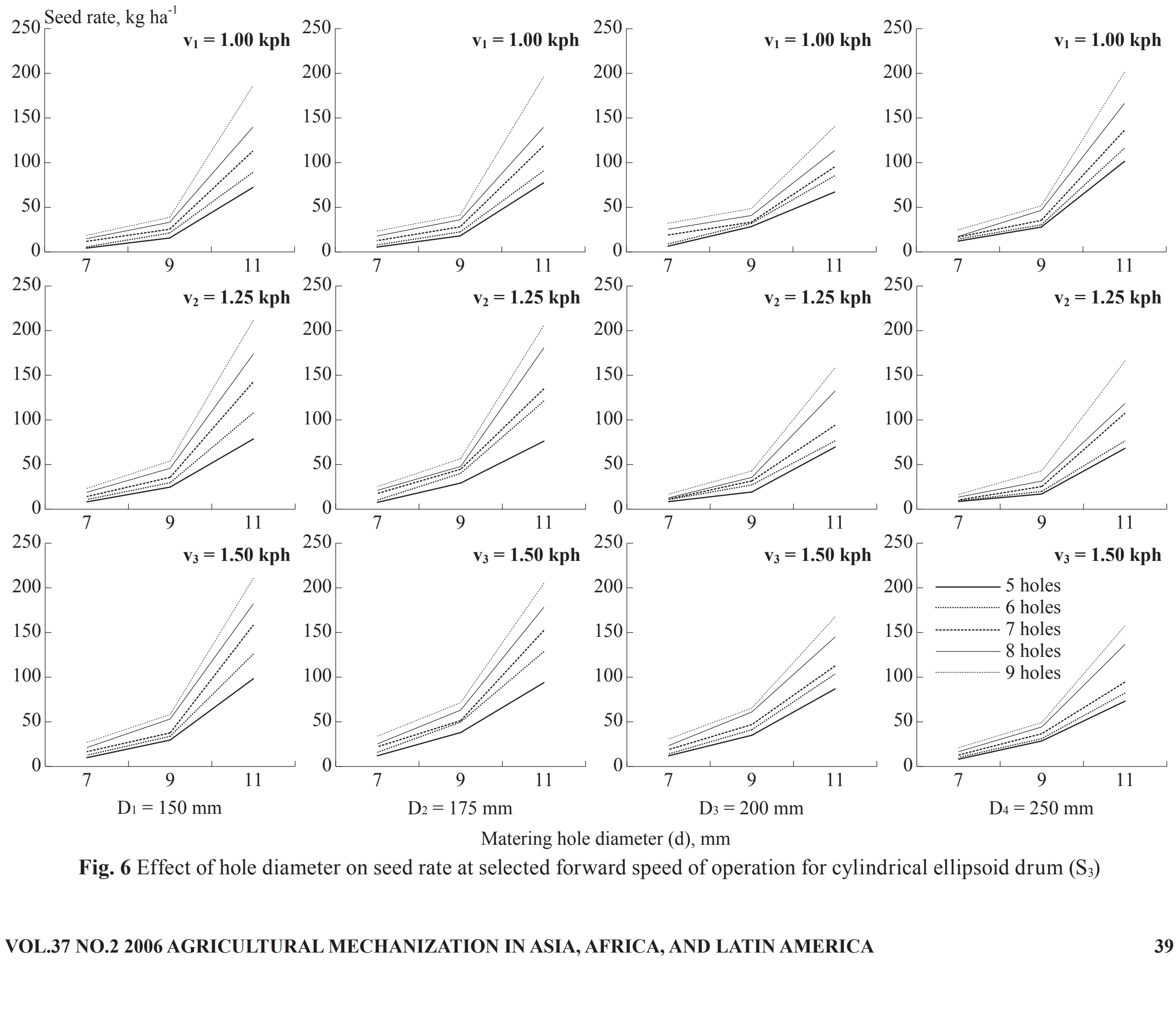


Fig. 6 Effect of hole diameter on seed rate at selected forward speed of operation for cylindrical ellipsoid drum (S_3)

gravitational force. Also the seed flow from the preceding holes might have added to the seed rate.

The increased drum diameter beyond 200 mm might have had an effect on the increased gravitational force and flow path trajectory of paddy seeds, which might be the reason for the increased seed rate. The increase in seed rate beyond 200 mm might also be due to the fact that more empty space is available which leads to free flow of seeds. This may also be due to the increased agitation leading to less bridging effect between the paddy seeds near the holes.

Statistical Analysis and Mathematical Modelling

In order to confirm the results obtained as discussed above and to optimize the shape of the drum, statistical analysis of the data was performed to assess the significance of the variables, namely, number of seed metering holes (X_1), diameter of seed metering holes (X_2), forward speed of operation (X_3), and the diameter of the seed drum (X_4) on the shape of the drum for seed discharge. The partial derivative of the best model for each shape was equated to zero. The simultaneous equations obtained on the above first order condition were solved and the results are presented in **Table 1**.

Drum shape	Solutions arrives			
	X_1 (Number of seed metering holes)	X_2 (Diameter of seed metering holes, mm)	X_3 (Forward speed of operation, m s^{-1})	X_4 (Diameter of drum, mm)
Cylindrical	-0.61	9.14	0.41	-100.66
Hyperboloid	9.11	6.82	0.295	183.59
Cylindrical ellipsoid	-0.766	9.93	0.288	198.00

Table 1 Solutions of variables for the statistical models

The hyperboloid drum gave the most realistic values for the selected variables based on the R^2 value and the solutions obtained from the partial derivative simultaneous equations. Since the objective was to get the desired seed rate (Y) of 80 kg ha^{-1}, in the analyzed model for hyperboloid drum Y was fixed at 80 kg ha^{-1} and corresponding oscillations were made within the realistic limits to obtain the values for X_1, X_2, X_3 and X_4. Considering the practical difficulty in the field operation the forward speed of operation (X_3) was fixed at 1.0 kph.

The seed drum diameter (X_4) value was fixed at 200 mm, which was closer to the solved value of 183.59 mm when the effect of drum curvature and gravitational forces were taken into account and the trajectory of movement of paddy seeds due to rotation.

The number of seed metering holes (X_1) was selected as 9 as the solved value was 9.11. By fixing the values of X_1, X_3 and X_4 as discussed above, for obtaining the desired seed rate level of 80 kg ha^{-1}, the diameter of the seed metering hole (X_2) was oscillated and accordingly the computed value was determined to be 9.9 mm. Hence the value of X_2 was fixed at 10 mm which is higher than the length of different paddy varieties studied (6.9 to 9.8 mm).

Percent Variation in Seed Discharge

The prototype drum with the optimized parameters was tested for per-cent variation in seed discharge with respect to time. The seed rate obtained in the prototype drum seeder with two levels of filling was investigated and the variation of seed distribution with respect to time is presented in **Fig. 7**. The percent variation in seed discharge was in the maximum range of - 60 to + 94 percent when the drum was filled to two-thirds of its capacity. Hence, filling was reduced to half of the drum capacity and the percent variation in seed discharge was reduced to a range from - 35 percent to + 90 percent. This may be due to the reduction in bridging effect of

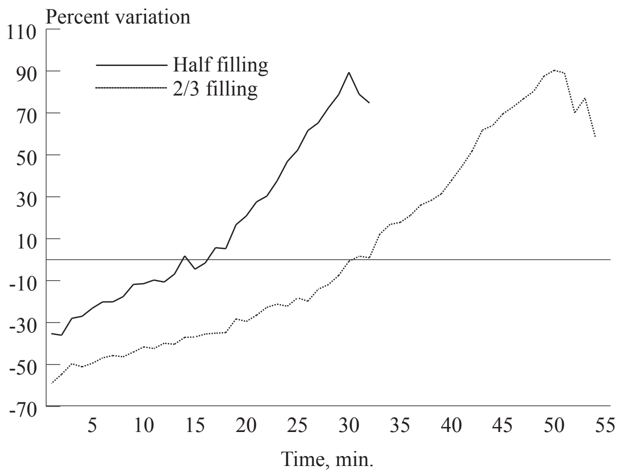


Fig. 7 Percent variation in seed discharge due to filling

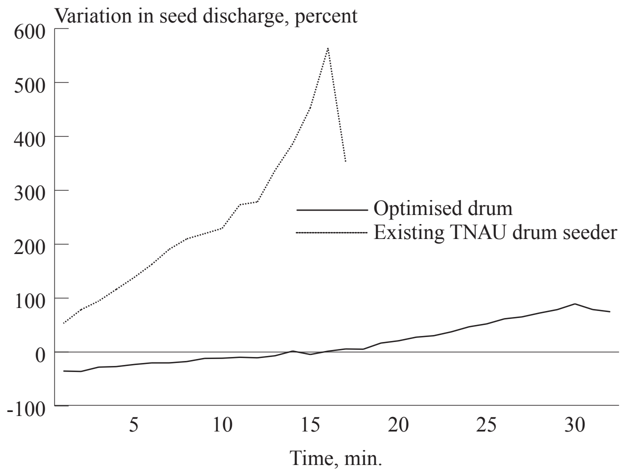


Fig. 8 Percent variation in seed discharge with respect to time

seeds. Since the percent variation in seed discharge was reduced when the drum was filled to half of its capacity, the filling level was selected as half of the capacity of the drum.

Effect of Baffles on Percent Variation in Seed Discharge

The seed rate obtained in the prototype drum seeder with and without baffles and with control (existing TNAU drum seeder) is depicted in **Fig. 8**. The time consumed for emptying the drum in the existing TNAU drum seeder was 17 minutes with higher seed rate, whereas in the prototype drum seeder it took 33 minutes to empty the drum with reduced seed rate. The percent variation in seed discharge of the prototype drum seeder with different types of baffles is illustrated in **Fig. 9**. The hyperboloid seed drum with optimized variables resulted in higher percentage variation of seed discharge from - 35 to + 90 percent than the recommended value leading to emptying of seed drum with in 33 minutes. But provision of baffles reduced this effect. However the baffles with round rods resulted in more negative percentage of variation when compared to flat baffles. Both types of fixtures of flat type baffles did not have significant variation in seed discharge. Hence, for the convenience of manufacturing, flat axial baffles were preferred over the inclined.

Description	Specification
Power source	One labour
Row to row spacing, mm	200
Shape of the drum	Hyperboloid
Number of rows, Nos.	4, 6, 8
Diameter of the drum, mm	200
Diameter of the seed metering hole, mm	10
Type of furrow opener	Wing type
Type of ground wheel	Lugged wheel
Diameter of ground wheel, mm	600
Operating speed, km h^{-1}	1.0
Level of filling	Half volume

Table 2 Specification of the prototype drum seeder with optimized variables

Conclusions

The specifications of the prototype drum seeder with optimized variables, based on the studies conducted, are presented in **Table 2**.

REFERENCES

Bharathi, T. 1996. Management options for seeding and weeding in wet-seeded rice. M.Sc.(Ag.) Thesis. Tamil Nadu Agric. Univ., Coimbatore.

Borlagdan.P.C., and M. Yamauchi. 1995. Seeder developed for direct sowing of rice under the puddled soil surface. IRRN. 20(1) 29-30.

Kandasamy, O.S.1987. Water, weed and nitrogen management for direct seeded, irrigated lowland rice. Ph.D. Thesis. Tamil Nadu Agricultural University, Coimbatore.

Pradhan, S.N. 1969. Mechanization of rice cultivation. Oryza 6: 67-71.

Wang, H.Y. and T.S. Sun. 1990. The characteristics of machine direct sown rice following wheat and the corresponding techniques. Acta Agricultural Universities Jiangxiensis 12: 34-39.

■■

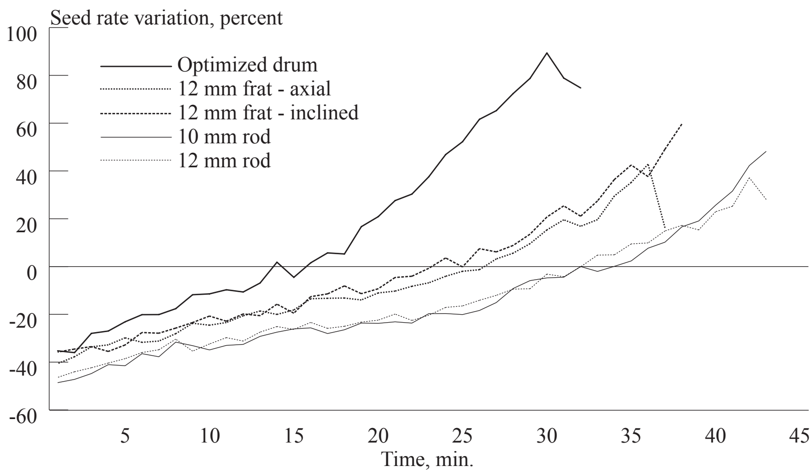


Fig. 9 Percent variation in seed discharge of the prototype drum seeder with different types of baffles

Reliability Analysis of Different Makes of Power Tillers

by
B. Shridar
Assoc. Professor
Department of Farm Machinery,
Agrl. Engg. College and Research Institute,
TNAU, Coimbatore-641 003
INDIA

P. K. Padmanathan
Research Scholar
Department of Farm Machinery,
Agrl. Engg. College and Research Institute,
TNAU, Coimbatore-641 003
INDIA

R. Manian
Professor and Head
Department of Farm Machinery,
Agrl. Engg. College and Research Institute,
TNAU, Coimbatore-641 003
INDIA

Abstract

Power tillers are visualized as an appropriate source of farm power of medium farms. The maintenance cost of the power tiller increases at a linear at rate during its lifetime. Failure of the machines at peak season cause many difficulties to the farmers. An investigation of the repair time in major systems was conducted and the collected data were analyzed through the Weibull distribution analysis and conclusions drawn. The respondents surveyed had Make A, Shrachi (water-cooled), Make B, Mitsubishi (air-cooled), and Make C, Mitsubishi (water-cooled), power tillers. The average annual working hours of all the power tillers ranged from 853 hours to 888 hours. The average working hours for the engine system was 1,332.24 hours for Make B, which was 0.4 and 4.67 percent higher than Make B and Make C respectively. The MTBF value for Make A was higher at 1,409.83 hours when compared to Make B and Make C. The average working period of clutch system was more for Make A (1,926.74 hours) followed by Make C (708.33 hours) and Make B (575.24 hours). The MTBF value for Make A, Make B and Make C was 1,953.13 hours 524.30 hours and 706.36 hours, respectively. The average working hours of the axle system was more for Make C (1,702.39 hours). The MTBF value for Make A was 2,388.51 hours, which was 46.56 and 25.86 percent higher than Make B and Make C respectively. The average working period of the rotary system was more for Make C (1,379.07 hours). The average working period of brake system was more for Make B (3,266.66 hours). The MTBF value of Make C was 2,497.88 hours, which was 43.16 and 48.98 percent higher than MTBF values of Make A and Make B, respectively.

Introduction

The power tiller industries have developed awareness of the maintenance of power tillers through a network of dealerships. But this maintenance network, though fiercely competitive, does not often systematically plan the need for repair and maintenance based on a well-defined database. The concept of reliability engineering may have to be applied to streamline the maintenance scenario, as reliability is a mathematical expression of the likelihood of satisfactory operation. Though the repair cost of the power tiller is high, the subsequent loss due to delay in carrying out repair is potentially much greater than the cost of repair. Under such condition any stoppage of the power tiller can cause sizable loss due to delay in carrying out the timeliness of farm operation during the peak season. Hence, reliability of the power tiller has become important, while the breakdown of an individual subsystem of a power tiller is an annoyance. To make allowance for these unpredictable breakdowns, the knowledge of the probability of failure, helps the farmer to plan more realistically for the farm operations. It is strongly believed that the application of reliability theory is feasible and necessary for proper utilization of the power tiller for time based operation. Similarly, the systematic analysis of break down of different components of power tillers over their service life, with a view to assess the reliability of different systems of a power tiller and its over all reliability for the field work, is keenly felt. A systematic study on the reliability analysis of the power tiller under Indian conditions has not been attempted so far, and, also, no work has been done on the reliability of the power tiller and its components and utilization pattern of it.

Review of Literature

Hunt (1971) reported that the reliability of the farmer's machines were so low that he would expect and plan for operation stoppages in each season. The complex harvesting machine systems were most prone to operation stopping breakdowns with the probability being 0.75 or greater each year for the larger farms. Garykrtz et al (1984) reported that a sample size of 15 or more was needed for the accurate implementation of Weibull graphing; otherwise, too much human error would be introduced. The tractor had 600 operational hours per year of which was used about 50 percent in tillage operation. Major breakdown occurred after 5 to 7 years of use. Under normal working conditions and with reasonable maintenance, the tractor could be used for 15 years. Singh (1986) reported that the frequency of engine breakdown for a 30-50 hp tractor was 22 percent more with a 50-90 hp at 5,000 cumulative hours of use. He reported that engine defects showed the highest percentage of the total of all the defects that occurred during the life of the tractor. Behl et al. (1987) concluded that the Weibull distribution was the best to represent the probability distribution of failure. They concluded that the Weibull parameters and cumulative distribution function could be represented by $F(t) = 1 - e^{-x}$. Svensson (1989) estimated that the maintenance cost of two wheel drive and four-wheel drive power sources increased at a linear rate during its life period. Rangasamy (1997) concluded that the Weibull parameters and the cumulative distribution function could be represented by mathematical equations.

Materials and Methods

The information on location, educational details, land holding and size, soil type, cropping pattern, details of the power tiller, operations performed with the power tiller, failure details, facilities for repair, maintenance aspects of power tiller, ergonomics aspects of power tiller, and socio economic aspects and constraints, if any, were collected from the respondents through a well structured questionnaire.

Selection of Sample

Among various taluks of Erode district, the number of power tillers (561) was found maximum in Gobichettipalayam taluk. Therefore, Gobichettipalayam taluk was selected for this study. In Gobichettipalayam taluk the three popular power tillers were Shrachi (water cooled), Mitsubishi (air cooled) and Mitsubishi (water cooled). The revenue villages in each block were listed based on the descending order of number of power tillers. The villages selected were the first 20 villages in Gobichettipalayam block, the first 9 villages in T.N.palayam, and the first 7 villages in Nambiyur block.

Selection of Power Tiller Respondents

For conducting the survey and collection of data in the study villages, a list of farmers owning power tillers was obtained from the Statistical department, Gobichettipalayam and the local dealers supplying the different makes of power tiller. Four farmers who owned power tillers were selected randomly in each selected village. The selected farmers were first asked whether they had purchased the power tiller before 1994. If his response was 'yes', he was considered as a sample unit and data were collected using the schedule. The basic data, such as the nature of repair and time of occurrence of such repair with reference to cumulative usage, were considered for selection of the sample power tiller for reliability analysis by adopting the following criteria.

The power tillers selected were those used mainly for agricultural operations. The other factor was the average annual usage in working hours. These two factors jointly induced maximum stress on agricultural power tillers and made them susceptible to failure. Hence, the basic data obtained on power tiller put to agricultural use would truly represent the functional effectiveness of the components of the power tiller for reliability analysis. The average annual usage of the power tiller was 800 hrs (Manian.and Swaminathan, 1991; Gupta, 1989). Hence, power tillers, which had served for a period ranging from five to 10 years, were considered for this study. Power tillers, involved in major accidents were not considered because their performance and failure pattern of components do not represent the standard performance and the normal wear and tear characteristics. In India, power tiller industries are manufacturing and supplying power tillers ranging from 8 to 15 hp. The 10 to 15 hp range appeared to be the dominant choice from the side of the manufacturers and the beneficiaries and was chosen for this study.

Types of repairs and their occurrence depend much on the performance of individual subsystems. The twenty-four subsystems were grouped under five major systems as detailed below.

i. Engine system - Liner, Piston, Piston rings, Valves, Crankshaft, Camshaft, Connecting rod, Fuel pump and Fuel injector

ii. Transmission system - Clutch cable, Clutch plate, Steering clutch and Gear box

iii. Axle - Axle, Axle bearing and Oil seal

iv. Rotary system - Chain and sprocket, Shaft, Gasket, Bearing and Rotary gear box

e. Brake system - Brake drum, Brake shoe and Brake lining

If failure occurs even in one of the subsystems, the power tiller cannot be put into use. Hence, the design and functional effectiveness of each system greatly contributes to the reliability of the power tiller. It is desirable to identify the effectiveness of each subsystem to have a clear idea about the overall performance.

Failure Pattern of Subsystem

A failure may be defined as any condition, which prevents, operation of a machine or which causes a level of performance below a recommended limit. Depending on the frequency of failure, the average life may vary. To find the average life of subsystems, the pooled average method was adopted. Weibull distribution is a very widely used tool in engineering practice. Its principal use is in the field of life phenomena. The distribution very well describes the life characteristics of a part because it is a three-parameter distribution. Hence, the Weibull model, which is more accurate in predicting the failure pattern of agricultural machinery, has been used to assess the reliability of the power tiller.

Method of Analysis

The collected data were classified and tables were formed to arrive at meaningful findings. The Shrachi power tiller respondents were categorized as Make A, Mitsubishi (air cooled) power tiller respondents were categorized as Make B and Mitsubishi (water cooled) power tiller respondents were categorized as Make C. Relevant data were used for performing percentage pooled average and Weibull distribution analyses.

Pooled Average Method

The failure data was taken for all the 24 subsystems from the completed questionnaire for each power tiller. In each subsystem, the failure data were taken for all the sample size of 144 power tillers. For each power tiller, there were a number of failures in each subsystem during the working period. For the individual subsystem, the over all minimum, maximum and average working hours were calculated for all the observed data. These observed values were used for making comparison with the expected values of the Weibull model developed for power tiller failure. This method was used by Singh (1986) to analyze the breakdown in tractors.

Weibull Distribution for Power Tiller Reliability

The data collected were statistically analyzed to identify the reliability of various sub systems of different makes of power tillers. The frequency failure distribution, for the above data was obtained for an interval of 200 hours from zero to a maximum value of 5,200 hours. This information formed the basis for reliability analysis. The number of power tillers that failed during a particular time interval was noted at the end of the interval.

Calculation of Observed Value of Failure

The cumulative frequency of failure of power tillers at different time intervals was calculated from the failure data of the system for different makes of power tiller. Then the cumulative frequency of failure for a particular time interval was divided by the sample size of the particular make of power tiller. This gave the observed value of failure distribution for the particular time interval.

Testing the Goodness of Fit of the Weibull Distribution

The Weibull model developed was tested for its suitability. Using the fitted Weibull distribution the expected frequency was computed. The goodness of fit was tested using the Chi-square statistics. The calculated Chi-square values were compared with the standard statistical table. Comparison of the calculated value of chi-square with the table values of chi-square (at the 95% level) indicated the goodness of fit of the Weibull distribution for the observed data.

Mean Time Between Failure and Variance

The mean time between failure (MTBF) of the subsystem in a system and its variance were calculated using the formulas from Rangasamy, 1997.

$$MTBF = \alpha_{\frac{1}{\beta}} \Gamma \left(1+\frac{1}{\beta}\right),$$

where

$\Gamma_{(p)}$ is the Gamma function given by

$\Gamma_{(p)} = \int_e \infty^{-x} x^{p-1} dx.$

The value of $\Gamma_{(p)}$ for various values of p were obtained using statistical tables.

Variance $\sigma^2 = \alpha^{2/\beta}\{\Gamma(1+2/\beta)-\{\Gamma(1+1/\beta)\}^2\}$

Coefficient variance = $\{\sigma/MTBF\}$ x 100

The values of MTBF, standard deviation and coefficient of variance were thus calculated. The MTBF provided the average lifetime of each component and the standard deviation gave a measure of variability of lifetime around the average value. For each component among the three makes of power tillers, the make that had the least coefficient of variation was preferred. The above data may be useful to give a guarantee for a particular subsystem by the manufacturer. It may also help the farmer to keep vigilance on the spare parts to be procured for the particular subsystem in order to avoid down time of the power tiller. The subsystem, which might require design modification due to poor reliability can also be identified from the data.

Results and Discussion

Reliability Analysis of Different Systems of Power Tiller

The failure data of five systems comprising 24 subsystem components for all the samples of power tillers were analyzed through the pooled average method of analysis and by the Weibull distribution analysis. The results are presented for the five systems of power tiller, which were engine, clutch, axle, rotary and brake.

Engine System

The failure data of the engine system comprised the following subsystem components; liner, piston, piston rings, valves, crankshaft, camshaft, connecting rod, fuel pump, and fuel injector.

i. Pooled Average Method for Engine System Failure

The results of the pooled average method for the engine system failure are presented in **Table 1**. The maximum working period of an engine was 3,600 hours (Make C) which was 2.77 percent higher than Make A and 16.66 percent higher than Make B. Based on the pooled average value, the average working period of the engine was higher for Make B (1,332.24 Hours).

ii. Weibull Distribution Analysis for Engine System Failure

There was no significant difference between the observed and predicted values of Weibull distribution for the engine system failure at different time intervals. The goodness of fit of the Weibull model of the equation developed for the engine system failure was tested with the Chi-square test. The observed and predicted cumulative probability were significant at 95 percent confidence level, which indicates the validity of the Weibull model developed for the engine system failures.

iii. MTBF of the Engine System

The MTBF of the subsystems components of the engine system for the different Makes of power tiller were calculated by substituting estimated values of the parameters β and α in the equation. Make A had a higher MTBF value of 1,409.83 hours while Make B had a lower MTBF value of 733.98 hours. The low MTBF value of Make B may be due to an insufficient cooling system and variation in engine system design. The MTBF of Make B was less than the values of Make A and C by 48 and 46 percent respectively.

Clutch System

The subsystem components of the clutch system were clutch cable, clutch plate, steering clutch, and gearbox.

i. Pooled Average Method for Clutch System of Failure

The results of the pooled average method for the clutch system failure are given in **Table 2**. Make C had the highest working period of 3,000 hours, which was 2.5 percent higher than Make A and 20 percent higher than Make B. The minimum value of working period was in the range of 100 hours (Make C) to 1,300 hours (Make A). Based on the pooled average value, the average working period of clutch system was more for Make A (1,926.74 hours). This was 70.14 percent higher when compared to the clutch system fitted in Make B and 63.24 percent higher than Make C. This may be due to variation in the clutch cable system of the power tillers.

ii. Weibull Distribution Analysis for Clutch System Failure

The goodness of fit of Weibull model of the equation developed for the clutch system failure was tested with the Chi-square test. The observed and predicted cumulative probability were significant at 95 percent confidence level, which indicates the validity of the Weibull model developed for the clutch system failure.

iii. MTBF of the Clutch System

The MTBF of the subsystem components of the clutch system for the different Makes of power tiller were calculated by substituting estimated values of the parameters β and α in the equation. It was found that Make A had a higher MTBF value of 1,953.13 hours while Make B had a lower MTBF value of 524.30 hours and Make C had 706.66 hours. This may be due to type of clutch present in the power tillers. Make A had double disc constant type clutch whereas Make B and Make C had multiplate dry disc type clutch.

Axle System

The components of the axle system were axle, axle bearing and oil seal.

i. Pooled Average Method for Axle System Failure

The results of the pooled average method for the axle system failure are given in **Table 3**. The maximum working period of the axle was

Power tiller make	Working hours		
	Minimum hours	Maximum hours	Average hours
Make A	350.00	3,500.00	1,326.83
Make B	420.00	3,000.00	1,332.24
Make C	212.00	3,600.00	1,270.03

Table 1 Results of the pooled average method for the engine system failure

Power tiller make	Working hours		
	Minimum hours	Maximum hours	Average hours
Make A	1,300.00	2,925.00	1,926.74
Make B	120.00	2,400.00	575.24
Make C	100.00	3,000.00	708.33

Table 2 Results of the pooled average method for the clutch system failure

4,200 hours (Make C), which was 45.23 percent higher than Make A and 9.52 percent higher than Make B. The lower value of working period was in the range of 200 hours (Make B) to 500 hours (Make A). Based on the pooled average value the average working period of axle system was more for Make C (1,702.39 hours). This was 16.73 percent higher when compared to the Make A and 22.47 percent higher as compared to the Make B.

ii. Weibull Distribution Analysis for Axle System Failure

There was no significant difference between the observed and predicted cumulative distribution function based on the Weibull model for the axle failure for the three Makes. The goodness of fit of the Weibull model of the equation developed for the axle system failure was tested with the Chi-square test. The observed and predicted cumulative probabilities were significant at 95 percent confidence level, which indicated the validity of the Weibull model developed for the axle system failures.

iii. MTBF of the Axle System

The MTBF of the subsystems components of the axle system for the different Makes of power tiller were calculated by substituting estimated values of the parameters β and α in the equation presented in section 3.4.3.6. The results of the analysis were tabulated along with coefficient of variance.

Table 4 shows that Make A had a higher MTBF value of 2,388.51 hours while Make B had a lower value MTBF value of 1,276.23 hours. The reason for this variation may be due to the variation in the design features of the axle system of the power tillers.

Rotary System

The components of the rotary system were chain and sprocket , rotary shaft, gasket, bearing and rotary gear box.

i. Pooled Average Method for Rotary System Failure

The results of the pooled average method for the rotary system failure are given in **Table 5**. The maximum working period of the rotary system was 4,000 hours (Make B), which was 68.12 percent higher than Make A, and 5 percent higher than Make C. The lower value of working period was in the range of 200 hours (Make A) to 350 hours (Make B). Based on the pooled average value, it was found that the average working period of the rotary system was more for Make C (1,379.07 hours). This was 44.20 percent higher when compared to the rotary fitted in Make A, and 6.96 per cent higher as compared to the Make B, which had a lower average working period of 769.41 hours.

ii. Weibull Distribution Analysis for Rotary System Failure

The goodness of fit of Weibull model of the equation developed for the rotary system failure was tested with the Chi-square test. The observed and predicted cumulative probabilities were significant at the 95 percent confidence level, which indicates the validity of the Weibull model developed for the rotary system failure.

iii. MTBF of the Rotary System

The MTBF of the subsystem components of the rotary system for the different Makes of power tiller were calculated by substituting estimated values of the parameters β and α in the equation. It was found that Make C had higher MTBF value of 1,432.96 hours while Make A had lower value MTBF value of 735.01 hours, which may be due to the poor design of the rotary system.

Brake System

The components of the brake system were brake drum, brake shoe and brake lining.

i. Pooled Average Analysis for Brake System Failure

The results of the pooled average method for the brake system failures are presented in **Table 6**. The maximum working period of the brake was 5,600 hours (Make B), which was 64.28 percent higher than Make A and 3.57 percent higher than Make C. The minimum value of working period was in the range of 300 hours (Make C) to 1,200 hours (Make B). Based on the pooled average value, it

Power tiller make	Working hours		
	Minimum hours	Maximum hours	Average hours
Make A	500.00	2,300.00	1,417.44
Make B	200.00	3,800.00	1,319.80
Make C	300.00	4,200.00	1,702.39

Table 3 Results of the pooled average mehod for the axle system failure

Power tiller make	MTBF (hours)	Standard deviation	Coefficient of variance
Make A	2,388.51	647.24	27.09
Make B	1,276.23	738.34	57.85
Make C	1,770.90	791.12	44.67

Table 4 MTBF hours, standard deviation and coefficient of variation for the axle system

Power tiller make	Working hours		
	Minimum hours	Maximum hours	Average hours
Make A	200.00	1,275.00	769.41
Make B	350.00	4,000.00	1,283.00
Make C	300.00	3,800.00	1,379.07

Table 5 Results of the pooled average method for the rotary system failure

Power tiller make	Working hours		
	Minimum hours	Maximum hours	Average hours
Make A	500.00	2,000.00	1,074.66
Make B	1,200.00	5,600.00	3,266.66
Make C	300.00	5,400.00	2,526.21

Table 6 Results of the pooled average method for the brake system failure

was found that the average working period of the brake system was more for Make B (3,266.66 hours), which was 203.97 percent higher than the brake system fitted in Make A that had minimum average working period of 1,074.66 hours.

ii. Weibull Distribution Analysis for Brake System Failure

There was no significant difference between the observed and predicted values of Weibull distribution for the brake system failure at different time intervals. The goodness of fit of the Weibull model of the equation developed for the brake engine system failure was tested with the Chi-square test. The observed and predicted cumulative probabilities were significant at 95 percent confidence level which indicates the validity of the Weibull model developed for the brake system failures.

iii. MTBF of the Brake System

The MTBF of the subsystems components of the brake system for the different Makes of power tiller were calculated by substituting estimated values of the parameters β and α in the equation. Make C had a higher MTBF value of 2,497.88 hours while the Make B value was lower at 1,276.25 hours. This may be due to the handling methods of the operator in operating the power tillers and the material of the brake system.

Conclusion

Based on the analysis of the results the following conclusions are drawn.

- The average working hours for engine system was 1,332.24 hours for Make B, which is 4.67 percent higher than Make C. The MTBF value for Make A was higher at 1409.83 hours than the MTBF value of Make B at 733.98 hours and of Make C at 1,354.48 hours. The low value of Make B may be due to an insufficient cooling system due to variation in engine system design.
- The average working period of the clutch system was more for Make A (1,926.74 hours), followed by Make C (708.33 hours) and Make B (575.24 hours). This may be due to variation in the clutch cable system of the power tiller. The MTBF values for Make A, Make B and Make C were 1,953.13 hours, 524.30 hours and 706.36 hours, respectively. This wide variation may be due to type of clutch present in the power tiller. Make A has a double disc constant type clutch, whereas Make B and Make C have multiplate dry disc clutch.
- The average working period of the axle system was more for Make C (1,702.39 hours). This was 16.73 percent higher than Make A and 22.47 percent higher than Make B. The MTBF value for Make A was 2,388.51 hours, which was 46.56 and 25.86 percent higher than Make B and Make C. The reason for this variation may be due to the variation in the design features of the axle system of the power tiller.
- The average working period of rotary system was more for Make C (1,379.07 hours). This was 6.96 percent higher than Make B and 44.21 percent higher than Make A. The MTBF value of Make C was 1,432.96 hours while Make A was lower at 735.01 hours, which may be due to the poor design of the rotary system.
- The average working period of the brake system was more for Make B (3,266.66 hours). This was 67.10 percent higher than Make A and 22.67 percent higher than Make C. The MTBF value of Make C was 2,497.88 hours, which was 43.16 and 48.98 percent higher than Make A and Make B, respectively. This may be due to the handling procedure of the operator in operating the power tillers and materials of the brake system.

REFERENCES

Behl, V. P, R. K. Malik, and D. P. Kataria, 1987. Predicting combine harvester reliability. Agricultural Engineering Today, 11 (6): 23-26.

Chaudhatry, R. P. and S. I. Ahmad, 1988. Field reliability of farm machinery. Agricultural Mechanization in Asia, Africa and Latin America, 19 (1): 73-78.

Gary Krutz, Lester Thompson, and Paul Claar, 1984. Design of Agricultural Machinery. John Wiley and Sons, New York, PP.139.

Gupta, J. P. and R. B. Ram, 1989. Performance of power tillers for rice cultivation in North Bihar region. Proceedings of the National Seminar on Role of Machineries in Maximizing Agricultural Production organized by ISAE held at Patna, India.

Hunt, D.1971. Equipment reliability. Indiana and Illinois Data. Transactions of ASAE, 14 (4): 742-746.

Manian, R. and K. R. Swaminathan, 1981. Choice of suitable farm power for arid and semi-arid regions. Paper presented at XVIII Annual Convention of ISAE held at Central Soil Salinity Research Institute, Kernal, India.

Rangasamy, K.1997. Investigation on the frequency of breakdown and reliability of selected makes of tractors and their systems. Ph.D. Thesis (Agrl.Engg). T.N.A.U. Coimbatore.

Singh, B.1986. Frequency of breakdown and reliability of different tractors and their system. Ph.D. Thesis (Agrl.Engg) G.B.Pant University of Agri. and Technology, Pantnagar.

Srivastava, A. C. 1984. Rational use of a general purpose farm tractor in India. Agricultural Mechanization in Asia, Africa and Latin America, 5 (2): 27-30.

Svenson, J.E.T.1989. Maintenance costs for farm machinery, Proceedings of the Eleventh international Congress on Agrl.Engg.Vol (1): 2669-2671. Published by A., Bolkema Ratterdam, Netherlands.

■■

Design and Development of a Two-Raw Saffron Bulb Planter

by
Mohammad-H. Saiedi Rad
Iranian Agricultural Engineering Research Institute,
Khorasan Agricultural Research Centre,
Mashhad, P.O.Box. 91735-488
IRAN
saiedi22@yahoo.com

Abstract

Iran, with 127.9 tons of saffron, holds the first position in world production. The major portion of this production belongs to Khorasan province with 4.8 kg/ha yield. Saffron bulbs are planted in the conventional way using labor intensive methods in Iran as well as other countries in the world. This method causes yield reduction and causes difficulty in harvesting operation. To overcome such problems, a planter was designed and constructed. The main objective was to design and construct a two-row planter for saffron bulbs, that wold plant the bulbs in 22 cm row-space and 15cm planting depth without damaging the bulbs. Four laboratory experiments were conducted to investigate the four important physical properties of size, density, bulk density and friction angle between bulbs and steel. For this purpose, many designs were evaluated, cup shape metering was selected, and a suitable cup was constructed. In this machine, the conveyor belt was equipped with four alternative row cups. Each cup carried one bulb, which was taken from the hopper. At the end of the way, bulbs of the two row cups fell into a furrow.

Introduction

Cultivation of saffron was fashionable in the center of Iran before Islam. At present saffron is planted in Iran, Spain, India, Greece and Italy (Rashed, 1989). Saffron in Iran occupies 24,000 hectares with 4.8 (kg/ha) yield. In 2000, 127.9 tons were produced. Iran consumes 20 percent of it's production and and exports the remainder (Iran agricultural ministry, 2000).

Saffron is a herb plant. The scientific name of saffron is Corcus Sativus L. and saffron belongs to Iriadace family. Since saffron is an auto triploid plant, it is sterile (Behnia, 1991). Saffron has asexual reproduction. Bulbs of saffron are white in color, spherical in shape, and hard and chubby in texture with a flat bottom and swollen heads. Bulbs are covered by crown fibers. Fibers emerge from the bottom of the bulbs, are narrow on the top of bulbs and protect the terminal buds. If fibers are separated from the bulb, a horizontal circle on the surface of bulb will be seen (**Fig. 1**) (Abrishami, 1983).

Lack of planting and harvesting mechanization is the major problem in Iran. Shortage of labor and high wages limit development of saffron cultivation since planting and harvesting take place in a short period of time. Planting time of saffron bulbs is from the middle of August to the middle of September. Two methods of planting are conventional in Iran:

1. Planting Several Bulbs in a Hole

With this method three to fifteen bulbs are planted in a hole. Holes are dug with a shovel, which keeps the surface of the field level.

2. Row Planting

Furrows are made by a furrower opener that is pulled with a tractor. Depth and row space of furrows are 15-20 and 15-30 cm, respectively. With this method, workers put bulbs into the furrows with 5-7 cm spacing in the row (Bagheri et al, 1990).

Bulbs that are lighter than 2 g cannot produce flowers in the first year and bulbs lighter than 6 g have the same limitation. Bulbs heavier than 14 g can produce 3.5 kg/ha saffron in the first year. Since heavy bulbs reproduce bigger bulbs, they increase yield in the first, second and third year. The minimum weight of a bulb for flower production in the first year is 6.5 g. The weight of the bulb effects the quantity of flower production (Mashayekhi et al, 1996). Behnia (1991) reported that increasing the number of bulbs per hectare, increases yield. He compared three planting methods (light, medium and heavy). Alavi et al (1996) concluded that the best planting density for saffron is 20 x 10 cm (row space and bulb space in row). He compared this method with two others (30 x 15 and 40 x 20 cm).

Materials and Methods

1. Measurement of the Physical Properties of Saffron Bulbs

Seven samples of bulbs were gathered from seven regions of Khorasan province. After removing the small bulbs (inappropriate for planting), from each sample, thirty bulbs were selected rondomly. The mass, volume and specific gravity were determined according to the method of Mohsenin (1970) as shown below. To determine the size of the bulbs, three different dimensions of the bulbs were measured using a suitable caliper.

$$G = \sqrt[3]{L_1 \times L_2 \times L_3} \quad \text{.............................(1)}$$

$$D = \frac{L_1 + L_2 + L_3}{3} \quad \text{.............................(2)}$$

$$S = \frac{G}{L_1} \quad \text{..(3)}$$

Table 1 Results of shape and experiments

L_1 (mm)	L_2 (mm)	L_3 (mm)	G (mm)	D (mm)	S
22.09	18.68	15.07	18.11	18.01	0.82

where L_1 , L_2 and L_3 are three perpendicular diameters of a bulb (L_1 is main diameter). The specific gravity of bulbs was calculated by following equation:

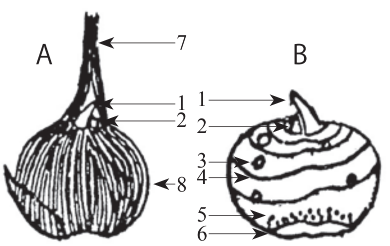
$$\rho = \frac{M}{V} \quad \text{..(4)}$$

where M is the bulb mass and was measured with an electronic balance. The volume, V, (cm^3) was measured by weighting the volume of displaced water into which the bulbs were immersed. Bulk density was calculated by equation (4). In this experiment a certain volume of bulbs (750 cm^3) was weighted by an electronic balance.

2. Choice of a Suitable Metering Device

Because of simularity between potato and saffron bulbs, several metering systems of potato planters were evaluated. This study showed that a belt conveyor metering system (bucket planter) with cups was the most suitable metering for the bulbs. Because of the fragility of the bulbs, spike picker metering could not be used. Moreover, the irregular shape of the bulbs did not permit use of a picker wheel metering system.

A bucket planter unit was mounted on a tool carrier. The tool carrier included a belt conveyor that moved the bulbs up vertically. The conveyor belt was equipped with four



1: Large terminal bud, 2: Small terminal bud, 3: Lateral bud, 4: lateral circles, 5: Location of previous root, 6: Previous bulb of last, 7: Protection cover of buds, 8: Crown cover (fobers)

Fig. 1 Bulb of saffron.
A: Without fibers, B: With fibers

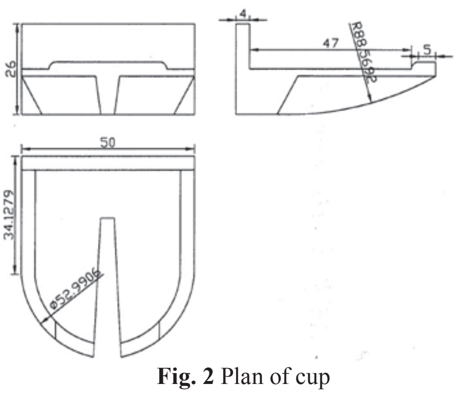


Fig. 2 Plan of cup

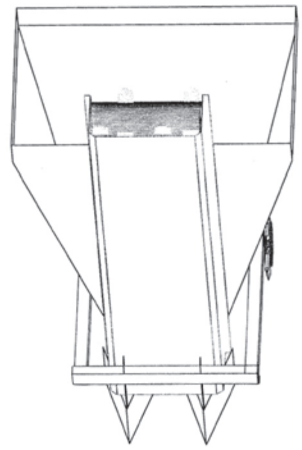


Fig. 3 Plan of bulb saffron planter

alternative row cups. Each cup carried one bulb, which was taken from the hopper. The row cups were arranged in such a way that the bulbs of two rows were placed in the same furrow.

A small tractor was used for saffron cultivation because the fields of saffron were very small (1,000-5,000 m^2). Hence, it was decided to design a two-row planter that would be mounted on a small tractor.

Construction of the Planter

1. Physical Properties

The geometric and arithmetical diameters, and the spherical shape were calculated for each bulb and the means were computed for each region. The total mean of the seven samples are shown in **Table 1**. The specific gravity and mean bulk density were 0.98 and 0.36 g/cm^3, respectively.

2. Design and Construction of Cups

The cups were designed and constructed based on the findings from shape and size experiments (**Fig. 2**) so that only one bulb could be accommodated in a cup. The

Fig. 4 Picture of saffron blub planter

cups were installed on a belt by two screws. The cups have a narrow groove at the bottom that catches the bulb surface fibers and separates the bulbs from each other. If a bulb falls on the cup up side down, the head of bulb moves in the groove and the bulb sits up correctly. The cups were cast aluminum and had a mean weight of 61 g.

3. Design and Construction of the Remaining Parts of the Planter

The hopper was constructed from steel with a capacity of 217 litters and could hold up to 78 kg of bulbs. The driving power was obtained by contact of the steel wheel with the ground. The wheel was comprised of two plates and six steel rods positioned between the plates. The rods change the diameter of wheel.

Evaluation of the Planter

Experiments showed that each cup carried one bulb from the hopper correctly. If bulbs were small, a cups would carry two bulbs. No bulb damage was detected by the metering system. **Table 2** shows eight possible states of operation of the planter. For these calculations, the mean weight of bulbs was 8 g.

REFERENCES

Abrishami, M. (1983). Saffron is red gold of salt desert. Publication of Tehran University.

Alavi, S. H. and M. Mohajeri. (1996). Effects of row spaces and bulb spaces on yield of saffron. Publication of Khorasan Agricultural Research Center.

Bagheri, K. and A. Hemati. (1990). Abstract of studying and researching on saffron. Publication of I.S.R.O.

Behnia, M. (1991). Cultivation of saffron. Publication of Tehran University.

Mashayekhi, K. and N. Latifi. (1996). Effects of bulbweight on saffron yield. Journal Of Iran Agri. Sinces, Vol 28, (1): 97-105.

Mohsenin, N. (1970). Physical properties of plant and materials. Gordon and Breach publishers.

Rashed, M.(1989). Report of saffron position in Spain. Publication of I.S.R.O. Statistics and information of agricultural ministry office. (2000). Statistics book of agriculture. Iran agri. ministry.

Speed of tractor (km/hr)	Diameter of wheel (mm)	Number of gear cog on shaft	Radial speed of pulley driver (rad/s)	Speed of conveyor belt (m/s)	Space of bulbs (mm)	Field capacity of planter (ha/hr)
3	250	14	7.136	0.499	85	0.06
3	300	21	3.966	0.277	140	0.06
3	250	21	4.754	0.333	120	0.06
3	300	14	5.95	0.416	100	0.06
4	250	14	9.52	0.666	85	0.08
4	300	21	5.29	0.37	140	0.08
4	250	21	6.348	0.44	120	0.08
4	300	14	7.94	0.55	100	0.08

Table 2 Coparasion of 8 possible states

Determination of the Optimum Moisture Content for Shelling Maize Using Local Shellers

by

I. K. Tastra
Agricultural Mechanization and
Food Technologist of RILET and
Food Technologist of ATA-272/NRC Project.
P.O. Box 66 Malang 65101, E. Java
INDONESIA

Erliana Ginting
Agricultural Mechanization and
Food Technologist of RILET and
Food Technologist of ATA-272/NRC Project.
P.O. Box 66 Malang 65101, E. Java
INDONESIA

Richard Merx
Agricultural Mechanization and
Food Technologist of RILET and
Food Technologist of ATA-272/NRC Project.
P.O. Box 66 Malang 65101, E. Java
INDONESIA

Abstruct

Optimum moisture content of maize for shelling was studied using local shellers operated in Kediri, E. Java, Indonesia. From August 1989 until May 1990, three types of local maize shellers were tested at three levels of grain moisture content and cylinder speed. The effective shelling capacity increased with an increase of the cylinder speed but decreased with an increase of the moisture content of maize. Therefore, shelling costs increased with an increase in moisture content. Mechanically damaged maize increased with increasing cylinder speed and with moisture content of maize. The total drying cost decreased with an increase in moisture content. Based on this relationship a mathematical model was developed. Solving the model with a tabular method in Lotus-123 program indicated that the optimum moisture content of maize for shelling, using sheller types SLM, KWT and TMO, was 32.5 %, 35.0 % and 35.0 % w.b, respectively. The minimum total costs of shelling and drying were Rp 3,573/t, Rp 3,176/t and Rp 3,315/t while the optimum grain mechanical damage was 18.4 %, 17.8 % and 21.1 %. It was concluded that each type of local maize sheller has different optimum grain moisture content. Among the three types of maize shellers tested, the best local maize sheller was the KWT type.

Introduction

Forty percent of the national maize production in Indonesia is grown in East Java province, concentrated mainly in the Kediri Area. Those farmers who do not use the maize for their own consumption shell directly after harvest at a high initial moisture content (over 25 % w.b.). Without drying and storing, the grain is then sold to a trader or to the Village Unit Cooperative (KUD). The latter is to assist the National Logistic Agency (BULOG), at the national level, in the supply of good quality maize. Although, at the KUD level repeated drying is done to bring the moisture content down to 14 %, deterioration during storage still arises, due to high initial mechanical damage, which is affected by the method of shelling (sheller type and speed), in combination with a high moisture content. In this way the storage problems are shifted from farm level to the KUD level. According to Thahir, et al (1988), drying maize as grain is more efficient than on the cob (ear). However, shelling maize ears at high moisture content (17-25 % w.b.) is reported to reduce mechanical damage and fuel consumption (Anonymous, 1987). Chowdhury and Buchele (1978) reported 60 % increase in damage (26.3 % to 42.0 %) after increasing the rotor speed of the cylinder type sheller from 450 to 650 rpm. Therefore, shelling maize at high grain moisture content seems to be contradictory to the effort of diminishing

Table 1 Cylinder speed (RPM) and grain moisture content (GMC) level for testing local maize shellers

Sheller type*	RPM (rpm)			GMC (% w.b.)		
	1	2	3	1	2	3
SLM	600	750	900	35	24	15
KWT	600	750	900	35	29	15
TMO	600	750	900	35	29	15

*To simplify the treatment names, representative shellers are named according to the name of the owner of the sheller (SLM: Mr. Slamet, KWT: Mr. Kawamoto and TMO: Tomo). Technically all shellers produced by local workshops are cylinder type shellers. The basic mechanism and the price of the shellers are presented in **Fig. 2** and **Appendix 1**.

the mechanical damage. However, no information is available yet on the optimum moisture content in maize for drying and shelling as one system to obtain optimal storability.

Practical information on the performance of various types of maize shellers operated in Kediri (Java's major centre of maize production) is not yet available. KUD may reduce the off-farm price for maize if the quality is beyond BULOG standard (3 % damaged kernels). Therefore improvement on the shelling quality is in the interest of both farmers (better selling-price) and the KUD (better storability). Optimum moisture content for shelling maize may diminish quality deterioration of maize during storage and so increase its economic value. Supply of good quality maize for food and feed industry and price control may be within reach. Optimizing the moisture content for shelling maize may increase efficiency of energy utilization per kg grain and so reduce machine operation costs as well as the total cost to produce one ton shelled maize ready to be stored or processed.

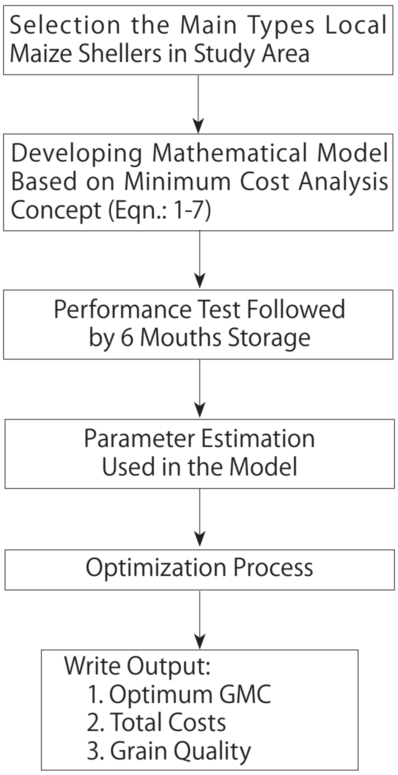


Fig. 1 Flow chart to determine optimal grain moisture content (GMC) level for testing local maize shellers

Objectives

1. To obtain the optimum moisture content in maize for shelling to improve the shelling quality and reduce the deterioration during storage.
2. To determine the best local maize sheller suitable for both traders and KUD.
3. To identify the constraints that improve the performance of local maize shellers.

Material and Methods

This experiment was carried out in the working area of KUD Nugro-

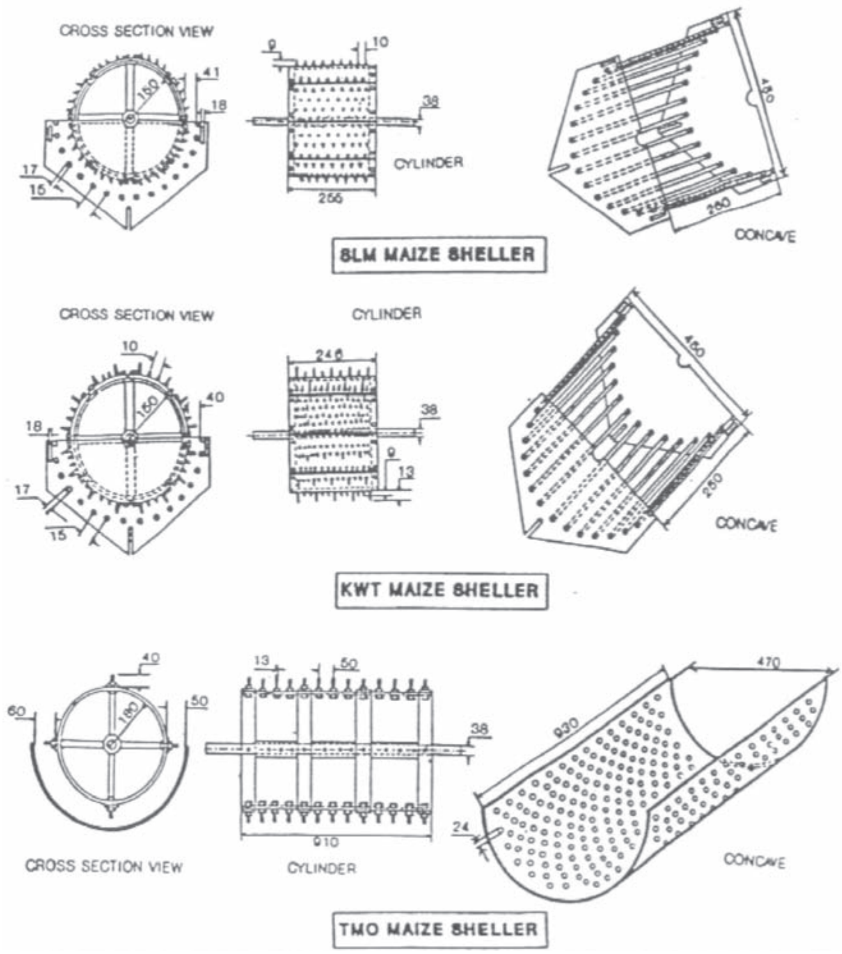


Fig. 2 Schematic diagram of the cylinder and shelling concave of the three local maize shellers

ho, Kediri, E. Java, Indonesia between August 1989 and May 1990. The flow chart to determine the optimal moisture content for shelling maize is presented in **Fig. 1**.

Three types of mobile shellers called SLM, KWT and TMO were used in this study. Schematic diagrams of the cylinder and shelling concave of the three local maize shellers are presented in **Fig. 2**. All shellers were run and hand-fed by two operators.

Based on a preliminary test, all runs were done at three levels of cylinder speed (RPM) and moisture content of maize (GMC) as presented in **Table 1**. The GMC, RPM and fuel consumption measurements were done using both the Stein L. moisture meter and oven method, a digital tachometer and a plastic glass measure.

After each run, the shelled grain was dried to a moisture content of 10-13 % (w.b.) on a drying floor. Subsequently, the maize was stored according to the normal procedures applied by the KUD Nugroho. Observations were made on effective shelling capacity (EC) and mechanical damage of grain (GD) with calculations made as shown below. **Appendix 1** gives the list of symbols, abbreviations and acronyms.

Appendix 1 List of symbols, abbreviations and acronyms used

Symbol	Description
EC	Effective shelling capacity (t/h)
SC	Shelled maize (kg)
TPS	Time needed for shelling (s)
GD	Percentage mechanically damaged grain (%)
WGD	Weight of mechanically damaged grain (g)
GIDG	Percentage damaged grain due to the insect infestation and mould growth (%)
WS	Weight of sample (g)
GMC	Grain moisture content (% w.b.)
FC	Fixed costs of maize shelling (Rp/year)
VC	Variable costs of maize shelling (Rp/year)
WT	Working hours available (h/year)
TDCOST	Total drying costs (maize cobs + shelled maize) (Rp/t)
TCOST	Total cost to produce 1 ton shelled maize ready to be stored (Rp/t)
SCOST	Shelling cost (Rp/t)
A,B,C,D,E,F	Constants
NRC	Nutrition related component of Project ATA-272
KUD	The village Unit Cooperative
BULOG	National Logistic Agency

EC = (SC/TPS)*3.6 ....(1)
GD = (WGD/WS)*100 % ....(2)

To determine the optimum moisture content for the shelling process, the concept of minimum cost analysis was used in this study (Thuesen, et al, 1981). To do this the following mathematical models were derived:

EC = A*(RPM/GMC)^B ....(3)
SCOST = (FC+VC)/(WT*EC) ......(4)
GD = C*EXP(D*(RPM*GMC)) ..(5)
TDCOST = E*EXP(F*GMC) ......(6)
TCOST = SCOST+TDCOST ....(7)

A homogeneity test (Gomez and Gomez, 1983) on coefficient B and D was made to determine if the effect of RPM and GMC on EC and GD were the same for all types of shellers before using Eqn. 7. As the results of tests were significantly different, the determination of the optimum GMC was required for each sheller.

The optimum GMC for the shelling process could be determined based on the minimum TCOST by using a tabular method. This process was done using Lotus-123 program. The quality of shelled maize, found at optimum GMC, in terms of

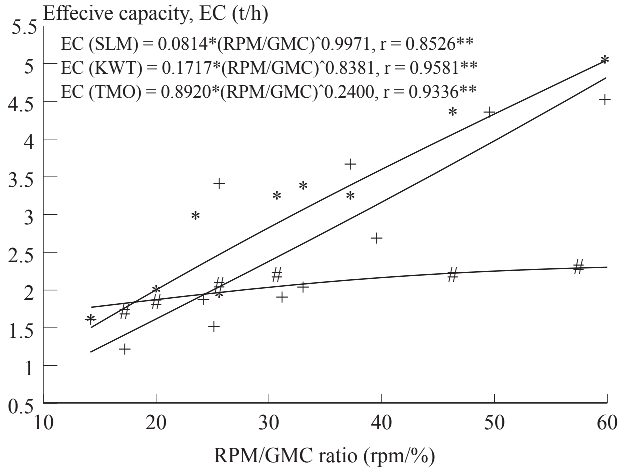


Fig. 3 Effect of cylinder speed and grain moisture content on effective capacity for three types of maize sheller (+ SLM, * KWT and # TMO)

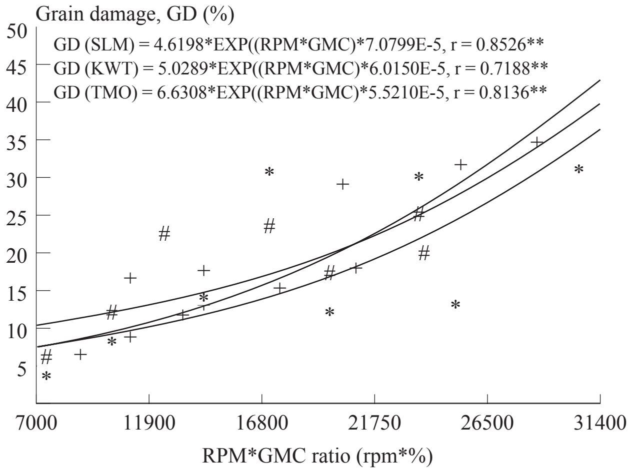


Fig. 4 Effect of cylinder speed and grain moisture content on grain damage for three types of maize sheller (+ SLM, * KWT and # TMO)

GD was calculated from Eqn. 5.

Results and Discussion

Effective Capacity (EC)

The ratio RPM/GMC had statistical significance on EC (**Fig. 3**). This phenomenon followed an exponential model where the coefficient determination (COD) was between 0.87 and 0.93. As the cylinder speed increased and/or the moisture content of the maize decreased, effective shelling capacity increased also. This is similar to the results of Chowdhury and Buchele (1978) and Nalbant (1990).

The homogeneity test of the regression coefficients indicated that the effect of RPM/GMC on EC was significantly different for all shellers. Among the local shellers tested, type KWT had the highest average EC (2.96 t/h) followed by type SLM (2.82 t/h) and type TMO (1.99 t/h).

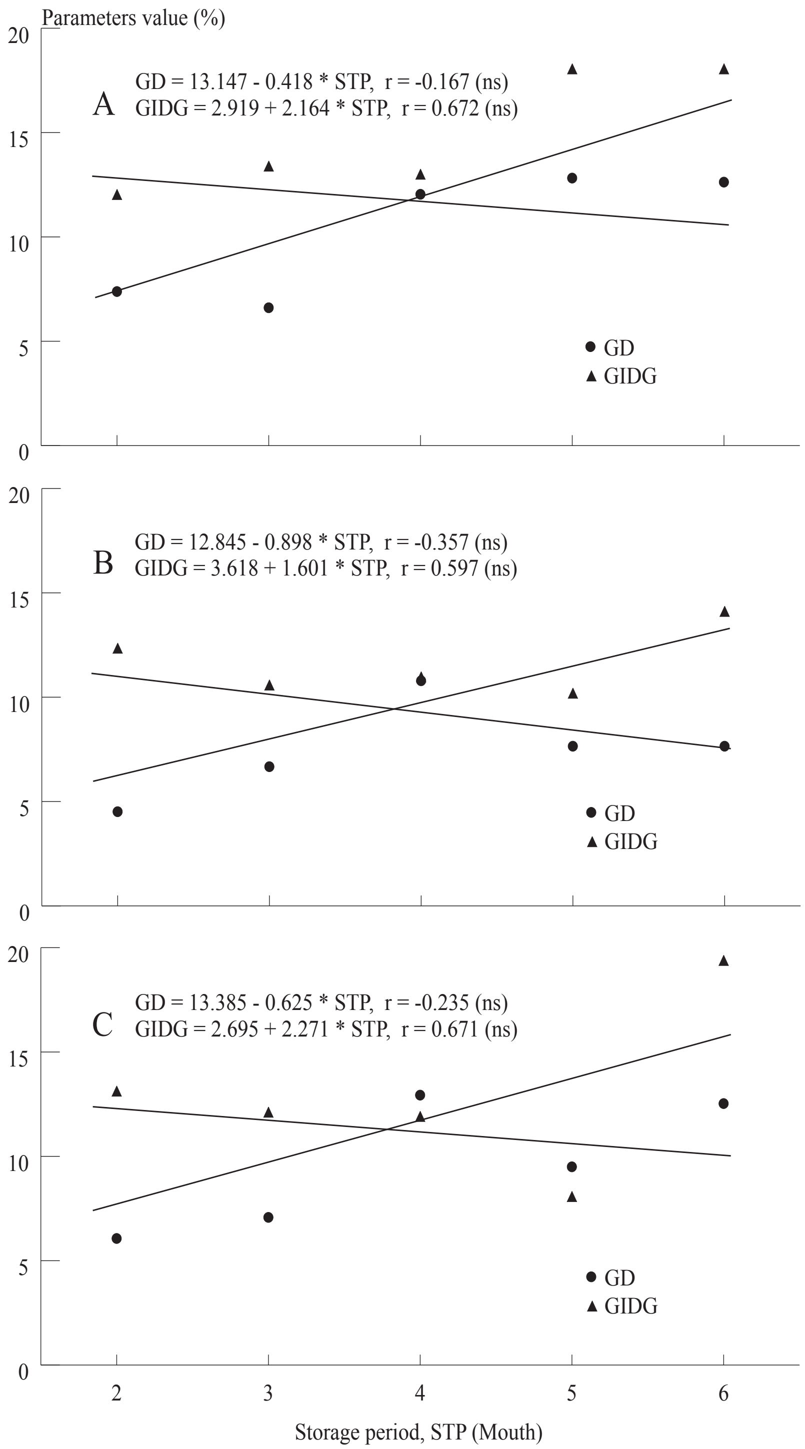


Fig. 5 Grain quality during six mouths storage of maize shelling with local maize shellers (A: SLM maize sheller, B: KWT maize sheller and C: TMO maize sheller)

Grain Mechanical Damage (GD)

The effect that the cylinder speed and moisture of maize had on mechanical damage is shown in **Fig. 4**. Generally, the GD increased with an increase of both the cylinder speed and the grain moisture content in SLM, KWT and TMO shellers. This phenomenon followed the exponential model with a COD between 0.52 and 0.85.

The homogeneity test of the regression coefficients indicated that the effect of RPM*GMC on GB was significantly different at a probability of 5 % for all three shellers. The highest average GD was found in the SLM sheller (11.7 %) while the average GD for the KWT and TMO shellers was 9.7 % and 11.2 % respectively. However, all shellers produced GD higher than 3 % due to the fixed arrangement of the shelling concave system used in the shellers (**Fig. 2**).

Optimum Grain Moisture Content (GMC)

Since the effects of RPM and GMC on EC and GD were different for all three shellers (**Figs. 3** and **4**), the optimum GMC was determined for each type of local sheller. The optimization process was done at a minimum cylinder speed (600 rpm), which is within the range of cylinder speeds suggested by the local workshop (600-700 rpm).

There are three steps in the optimization process. First, there is the calculation of the shelling cost (Eqn. 4) as determined by the effective capacity (Eqn.3), the fixed and variable costs for each sheller and the total working hours available per year (**Appendix 2**). Secondly, the total drying cost (Eqn. 6), which is the sum of the costs needed to dry maize cobs and shelled maize, must be calculated. The parameter used in the TDCOST model is based on information gathered from KUD Nugroho staff and observations made during the drying process. The final step is the calculation of the total costs, which is the sum of the shelling costs and total drying costs (Eqn. 7).

By using the tabulation method in Lotus-123, the minimum TCOST for SLM, KWT and TMO sheller was Rp 3,573/t, Rp 3,176/t, and Rp 3,315/t, respectively (**Appendix 3**, **4** and **5**). At these minimum total costs the optimum GMC was 32.5 %, 35.0 % and 35.0 % w.b., respectively.

Grain Quality During Storage

High initial mechanical damage during the shelling process had no significant effect on insect infestation and mold growth after storage of 6 months (**Fig. 5**). The average GD for SLM, KWT and TMO shellers was 11.7 %, 9.7 % and 11.2 %. The average GIDG during this period at an average temperature of 29 ºC and relative humidity of 73 % was 10.5 %, 9.2 % and 10.6 %. This result indicated that although the initial GD was rather high, its effect on GIDG could be kept within the limits by immediate drying of the shelled maize down to a moisture content of 10-13 % w.b.

Social-Economic Implications

The use of mobile shellers, which are now operated in the working area of KUD Nugroho, Kediri, E. Java has a positive social-economic impact on the users, traders and the KUD. The impact is different for each group due to the differences in needs and objectives.

The main positive impact of using mobile maize shellers for the farmer is the reduction in workload during the shelling process as well as the reduction in costs of shelling. The owners of the shellers can make additional income by renting out their machines, while the local work-

Appendix 2 Estimation of fixed and variable costs of the local maize shellers operated in KUD Nugroho Kediri, E. Java, Indonesia

Items	Sheller type		
	SLM	KWT	TMO
Initial cost (IC) (Rp/unit)*	1,650,000	1,700,000	2,000,000
Depreciation (D) (Rp/ year)	330,000	340,000	400,000
Interest (Rp/year)	178,200	183,600	216,000
Fixed cost (FC) (Rp/year)	506,200	523,600	616,000
Labor (Rp/year)	720,200	720,000	720,000
Fuel (Rp/year)	86,950	91,728	67,473
Repair (Rp/year)	49,500	51,000	60,000
Variable cost (VC) (Rp/year)	856,450	862,728	847,473

Assumption:

1. Working day: 120 days/year
2. Interest rate: 18 %/year
3. Machine life (N): 5 year
4. Fuel consumption (KWT): 0.096 l/h/hp
   Fuel consumption (TMO): 0.054 l/h/hp
   Fuel consumption (SLM): 0.091 l/h/hp
5. Fuel price: Rp 245/l
6. Diesel engine (KWT): 6.5 hp
   Diesel engine (TMO): 8.5 hp
   Diesel engine (SLM): 6.5 hp
7. Working hours (WT): 600 hours/year
8. Salvage value (S): 0 % * IC
9. D = (IC - S) / N
10. Repair: 3 % * IC
11. Wage rate: Rp 3,000/day/man
12. Operater: 2 persons
13. Custom rate: Rp 4,000/t
14. Custom rate: Rp 4,000/t

* In 1990, 1 US$ = Rp 3,000

Appendix 3 Calculation of optinum GMC for shelling process using sheller type SLM

FC (Rp/year)	VC (Rp/year)	WT (hours)	A(1)	B(1)	E(2)	F(2)	RPM (rpm)	GMC (% w.b.)	SCOST(3) (Rp/t)	DCOST(4) (Rp/t)	TCOST(5) (Rp/t)
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	15.0	706.04	3,057.51	3,763.55
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	20.0	940.61	2,726.28	3,666.88
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	25.0	1,175.00	2,430.93	3,605.93
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	30.0	1,409.25	2,167.58	3,576.83
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	30.5	1,432.67	2,142.87	3,575.54
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	31.0	1,456.09	2,118.44	3,574.53
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	31.5	1,479.51	2,094.29	3,573.80
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	32.0	1,502.92	2,070.41	3,573.33
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	32.5	1,526.34	2,046.81	3,573.15*
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	33.0	1,549.75	2,023.47	3,573.22
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	33.5	1,573.16	2,000.40	3,573.56
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	34.0	1,596.57	1,977.60	3,574.17
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	34.5	1,619.98	1,955.05	3,575.03
508,200	856,450	600	0.0814	0.9971	4,312.795	-0.02293	600	35.0	1,643.39	1,932.76	3,576.15

(1)Constant of Eq. 3, (2)Constant of Eq. 6, (3)Eq. 4, (4)Eq. 6, (5)Eq. 7

shops make money by producing the shellers. For the traders and the KUD, maize losses can be reduced due to the speeding up of the shelling process.

However, there are also some negative aspects. Since the mobile local maize shellers are not accompanied by a manual on how to operate the sheller at various GMC and RPM, the maize losses due the shelling process are difficult to quantify at the KUD level. In fact, the maize losses during the shelling process using the local shellers appeared much higher than the BULOG standard (3 % damaged kernels). At optimum GMC (lowest TCOST) for the shelling process at a cylinder rotation speed of 600 rpm, the GD (Eqn. 5) was 18.4 %, 17.8 % and 21.1 % for the SLM, KWT and TMO shellers, respectively. Based on the Directorate Food Crops Agriculture (1988) in Purwadaria (1989), an increase of 1 % damage will reduce the price of shelled maize by Rp 0.6/kg. Therefore, the maize losses in terms of cash value will be Rp 9,240/t, Rp 8,880/t and Rp 10,860/t for the SLM, KWT and TMO shellers, respectively. Since the demand for maize exceeds the supply, most of the maize is directly processed into animal feed. However, for the long term objective of national maize production the negative impact of using local maize shellers should be taken into account.

The negative impact on the users is that the quality of the shelled maize is often uncontrollable due to the inferior quality of the shellers. The owners, who buy the shellers from local workshops dealers, also face problems in managing their shellers economically.

Conclusions

1. The optimum moisture content at a cylinder speed of 600 rpm was 32.5 %, 35.0 % and 35.5 % (w.b.) for

Appendix 4 Calculation of optinum GMC for shelling process using sheller type KWT

FC (Rp/year)	VC (Rp/year)	WT (hours)	A(1)	B(1)	E(2)	F(2)	RPM (rpm)	GMC (% w.b.)	SCOST(3) (Rp/t)	DCOST(4) (Rp/t)	TCOST(5) (Rp/t)
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	15.0	611.31	3,057.51	3,668.82
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	20.0	777.98	2,726.28	3,504.26
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	25.0	937.97	2,430.93	3,368.90
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	30.0	1,092.83	2,167.58	3,260.41
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	30.5	1,108.07	2,142.87	3,250.94
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	31.0	1,123.28	2,118.44	3,241.72
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	31.5	1,138.44	2,094.29	3,232.73
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	32.0	1,153.57	2,070.41	3,223.98
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	32.5	1,168.65	2,046.81	3,215.46
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	33.0	1,183.70	2,023.47	3,207.17
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	33.5	1,198.71	2,000.40	3,199.11
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	34.0	1,213.69	1,977.60	3,191.29
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	34.5	1,228.63	1,955.05	3,183.68
523,600	862,728	600	0.1717	0.8381	4,312.795	-0.02293	600	35.0	1,243.54	1,932.76	3,176.30*

(1)Constant of Eq. 3, (2)Constant of Eq. 6, (3)Eq. 4, (4)Eq. 6, (5)Eq. 7

Appendix 5 Calculation of optinum GMC for shelling process using sheller type TMO

FC (Rp/year)	VC (Rp/year)	WT (hours)	A(1)	B(1)	E(2)	F(2)	RPM (rpm)	GMC (% w.b.)	SCOST(3) (Rp/t)	DCOST(4) (Rp/t)	TCOST(5) (Rp/t)
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	15.0	1,128.17	3,057.51	4,185.68
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	20.0	1,208.81	2,726.28	3,955.09
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	25.0	1,275.32	2,430.93	3,706.25
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	30.0	1,332.36	2,167.58	3,499.94
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	30.5	1,337.66	2,142.87	3,480.53
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	31.0	1,342.89	2,118.44	3,461.33
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	31.5	1,348.05	2,094.29	3,442.34
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	32.0	1,353.16	2,070.41	3,423.57
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	32.5	1,358.20	2,046.81	3,405.01
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	33.0	1,363.19	2,023.47	3,386.66
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	33.5	1,368.12	2,000.40	3,368.52
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	34.0	1,372.99	1,977.60	3,350.59
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	34.5	1,377.81	1,955.05	3,332.86
616,000	847,473	600	0.892	0.24	4,312.795	-0.02293	600	35.0	1,382.57	1,932.76	3,315.33*

(1)Constant of Eq. 3, (2)Constant of Eq. 6, (3)Eq. 4, (4)Eq. 6, (5)Eq. 7

the SLM, KWT and TMO shellers, respectively.

2. In terms of total costs to produce 1 ton of shelled maize, the best local maize sheller is type KWT (Rp 3,176/t).

3. Grain mechanical damage at optimum grain moisture content is 18.4 %, 17.8 % and 21.1 % for the SLM, KWT and TMO shellers, respectively.

4. Although the mechanical damage is higher than the BULOG standard (3 %), there is no significant effect on biological damage during six months storage. Average GIDG is 10.5 %, 9.2 % and 10.6 % for the SLM, KWT and TMO sheller, respectively. Nevertheless, these losses are considered too high; consequently, storage methods of the KUD should be improved.

Recommendations

1. The optimization model used in this study needs further development and verification. The model used is without constraints. Identification of the constraints in using local maize shellers as a component of the maize postharvest system is very important for the development of an appropriate local maize sheller that is technically possible, economically feasible and socially acceptable.

2. While modifying the optimization model used, immediate research to improve the basic mechanism (concave system) of maize shellers is needed for all shellers to reduce grain mechanical damage.

3. Follow up on testing to determine the correlation between mechanical damage, moisture content and biological damage (storage losses) is needed.

REFERENCES

Anonymous (1987). Small-scale Maize Milling. Technical memorandum No. 7. International Labour Office, Geneva.

Chodhury, M. H. and Buchele W. F. (1978). The nature of corn kernel damage inflicted in the shelling crescent of grain combines. Transaction of ASAE, 21(4):610-614.

Gomez, K. A. and A. A. Gomez (1983). Statistical Procedures for Agricultural Research. Second Edition. John Wiley and Sons, Inc. New York p. 357-379.

Nalbant, M. (1990). Mechanical damage on corn kernel in shelling corn ear. AMA, 21(2):37-40.

Purwadaria, H. K.(1989). Konsepsi pengembangan peralatan panen palawija untuk tingkat pedeaaan. Makalah disampaikan pada Seminar dan Kongkres Perhimpunan Teknik Pertanian Indonesia tanggal 19 - 21 Januari 1989. Universitas Brawijaya, Malang, Indonesia. P. 18.

Thuesen, H. G., W. J. Fabrycky and G. J. Thusen (1981. Engineering Economy. 5th Edition, Prentice-Hall of India. New Delhi-110001.

Thahir, R., Soedaryono, J., Setiawati and Sumardi (1998). Paper presented at Workshop on the National Coordinated Research Program on Corn and grain legume, Bogor 21-23 June 1988, Indonesia. P. 9.

The Influence of Various Factors on Tractor Selection

by
Ali Aybek
Department of Agricultural Machinery,
Kahramanmaras Sutcu Imam University,
Kahramanmaras,
TURKEY
aaybek@ksu.edu.tr

Ismet Boz
Department of Agricultural Machinery,
Kahramanmaras Sutcu Imam University,
Kahramanmaras,
TURKEY
ismetboz@ksu.edu.tr

Abstract

The main purpose of this study was to determine the influence of various factors on tractor selection among Kahramanmaras farm operators. The study included 214 randomly selected farm operators. The influence of various technical features of farm tractors on farmers' purchasing decision was investigated. The second objective of the study was to identify the economic and social factors that influence farmers' preference. Results showed that fuel consumption and power delivered by the tractor were the most important technical features while price and brand of selected tractor were the most important economic and social factors. Pearson correlation coefficient between the variables of farm size and tractor power ratings was r = 0.60, suggesting that farm size was properly taken into account when choosing a farm tractor.

Introduction

Agricultural mechanization is a complementary factor for increasing the efficiency and economic use of other farm technologies as well as for improving work conditions of farm operations. Besides these characteristics, agricultural mechanization takes the largest share among all agricultural investments within a farm operation (Sabanci and Aybek, 1990). Except land purchasing costs, the total production costs of Turkey's farm operations is approximately $400 per hectare, 50 % of which consists of machinery costs. The remaining costs include labor (11 %), fertilizers (10 %), seeds (10 %), chemicals (6 %), and other costs (13 %) (Anonymous, 1999).

Farmers need to be carefull when purchasing and using their machinery because machinery costs constitute 50 % of the total production costs in farm operations. For this purpose, farm size and relevant farming practices need to be taken into account. If farmers consider these factors in purchasing and using farm machinery, they will probably increase the efficient use of their available resources. Economic sustainability of farm operations depends partially on the ability of managers in proper selection and management of farm machinery (Grisso et al, 1988; Srivastava et al, 1993).

The majority of farms in Turkey are small. Historicaly, farm operators have purchased their farm machinery without considering scientific criteria, which have caused many farmers to purchase high capacity machinery with high prices. This situation has increased production costs per unit land. The findings of a study showed that a farm of five hectares has eight times the machinery cost per hectare as compared to a farm of 50 hectares (Anonymous, 2002 a). In addition to the inefficiency in machinery selection, there are many farmers struggling to prevent leaving farming because of outdated agricultural technologies and farm machinery. All of these factors increase production costs, decrease the quality and quantity of agricultural production and limit the opportunity for Turkey's agricultural products to compete in international markets.

The tractor is the most important machinery item among all other farm machinery (Liljedahl et al, 1989). Proper selection of a tractor is a basic factor influencing the economic sustainability of farm operations (Isik, 1996). The proper selection is determined by factors such as farm size, production system, duration of production process, land structure, soil structure and climatic conditions (Demirci, 1986; Isik, 1988).

Kahramanmaras, with 472,031 hectares of cultivated land, is one of the leading agricultural provinces of Turkey. Agriculture is the income source of more than half of the population in the region. Soil and climatic conditions of the region make it possible for Kahramanmaras farm operators to grow wheat, barley, cotton, sugar beets, sunflower, red pepper, and many other crops (Anonymous, 2002 b).

According to 1998 data, there were 8,104 tractors, 8,655 tools, and 83 combines around Kahramanmaras (Anonymous, 2002 c). If the average tractor power is taken as 40.6 kW (Sabanci and Akinci, 1994), the mechanization level in the region is about 0.70 kW/ha, and the average member of tools per tractor is about five. In Turkey, on the other hand, the mechanization level is 1.33 kW/ha while the average member of tools per tractor is five. These numbers indicate that the mechanization level in Kahramanmaras is lower than that of the average of Turkey. Although the number of tools in the region is equal to the average of Turkey, the need for new agricultural technology in the region continues to increase. This is because of changing crop patterns, second crop production, and increasing demand for the crops cultivated in the region, especially for cotton and corn. In order to modernize agriculture, the increasing demand for new agricultural technologies will also increase the need for purchasing new tractors in the region.

The overall purpose of this study was to determine the factors taken into consideration by Kahramanmaras farm operators when purchasing a tractor. The specific objectives were:

1. to identify the sellers from whom farmers purchase their tractors, and the status of tractor as being new or used;
2. to identify the influence of technical factors that are considered by farmers when purchasing a tractor;
3. to identify the influence of economic and social factors which are considered by farmers when purchasing a tractor;
4. to determine any correlation that might exist between the variables of farm size and the delivered power of tractor; and
5. to develop research based recommendations that will assist farmers in the selection of the optimum tractors for their farm.

The findings of this study should provide valuable input for farmers, tractor manufacturers, agricultural extension organizations, and agricultural researchers in the region.

Research Methodology

This study used the survey method for data collection. The participants were 214 randomly selected farm operators from the plain villages of Kahramanmaras central district, Turkoglu, and Pazarcik towns. A questionnaire was developed that considered earlier work and specific characteristics of agricultural mechanization in the region. The study included two sections. The first section consisted of nine questions to identify technical features farmers consider when purchasing a tractor. The second section consisted of another nine questions to identify economic and social factors that may influence farmers when purchasing a tractor. A five point Likert type scale with 1 = very important, 2 = important, 3 = indifferent, 4 = not important, and 5 = absolutely not important was developed. A panel of experts established validity for the data collection instrument. The instrument was pre-tested and slight changes were made for establishing reliability. Date were collected in September to December 2002. SPSS (Statistical Package for the Social Sciences) was used for data analyses.

Descriptive statistics were used to achieve the first three objectives of the study. Because the information related to objectives 2 and 3 were collected on a five point Likert type scale, the means, were interpreted using a scale where 1.49 or less = very important; 1.50-2.49 = important; 2.50-3.49 = indifferent; 3.50-4.49 = not important; and 4.50-5.00 = absolutely not important was developed. Pearson correlation coefficient was used to achieve the fourth objective of the study. The variables of farm size and tractor power were measured as interval variables. Pearson correlation coefficient can best describe the correlation between two variables if they are measured in intervals (Voelker and Orton, 1993). In order to interpret the level of correlation between two variables, the Davis (1971) correlation interpretative scale was used. This scale is presented in **Table 1**.

Correlation coefficient (r)	Description
0.70- +	Very strong correlation
0.50-0.69	Strong correlation
0.30-0.49	Moderate correlation
0.10-0.29	Low correlation
0.01-0.09	Negligible correlation

Table 1 Interpretation of correlation coefficients (Davis, 1971)

Technical features	Level of importance	
	Mean	Std. deviation
Fuel consumption	1.22	0.58
Power delivered by the tractor	1.29	0.62
Availability of spare parts	1.32	0.63
Availability of maintenance services	1.38	0.57
Features of power take off	1.43	0.65
Features of tires	1.52	0.66
Features of transmission	1.53	0.72
Power steering	1.89	0.97
Double traction	2.42	1.33

Table 2 Technical features which farmers take into account when purchasing a tractor

Research Results

Results showed that 46 % of respondents purchased their tractors from dealers, 29 % from commissioners, and 25 % from other farmers. Fifty-seven percent of the purchased tractors were used while 43 % were new.

Of the nine technical features, five were in the very important, and four were in the important interpretative category as shown in **Table 2**. There were no items in indifferent, not important, and absolutely not important interpretative categories. Fuel consumption was the most important technical feature for selection of a tractor. This was followed by the power of the tractor, availability of spare parts, availability of maintenance services, and the power take off. The items that respondents ranked as important were tires, transmission, and availability of power steering and double traction. There were no items in indifferent, not important, and absolutely not important interpretative categories.

Table 3 shows that, out of the nine economic and social factors, four were in the very important, four were in the important, and one was in the indifferent interpretative category. There was no item in the not important and absolutely not important interpretative categories. Of the nine economic and social factors the most important one was price of tractor. This was followed by brand of tractor, having a cab, being a commonly used tractor in the region, using similar tractor earlier, desire of household members, physical appearance of tractor, tractor adds on mass media, and influence of neighbor farmers.

Mean farm size and tractor power were calculated as 16.66 ha, and 50.1 kW, respectively (**Table 4**). The average tractor power in the research area (50.1 kW) was found to be 9.51 kW higher than that of Turkey, which was calculated as 40.6 kW by Sabanci and Akinci (1994). Pearson correlation coefficient between tractor power and farm size was calculated as $r = 0.60$ ($n = 214$). According to Davis's interpretative scale there was a strong correlation between these two variables indicating that, as farms get larger, farmers tend to purchase more powerful tractors.

Summary, Conclusions, and Recommendations

This study investigated the influence of various factors that are taken into consideration by Kahramanmaras farm operators on tractor selection. From a random sample of 214 farm operators, 46 % of respondents purchased their tractors from dealers, 29 % from commissioners, and 25 % from other farmers. Fifty-seven percent of the purchased tractors were used while 43 % were new. Fuel consumption and power of tractors were considered the most important technical features while power steering and double traction were the least important technical features. Price and brand of tractors were considered the most important economic and social factors while tractor advertisements on mass media and influence of neighbor farmers when purchasing a specific tractor were the least important. The average tractor power in the research area was higher than that of Turkey. There was a strong positive correlation between farm size and tractor power.

Used tractors in the region have a better market value than new tractors. This is because large farmers want to sell their tractors, after using them several years, and replace them with a new one. Small farmers, consisting of the majority of farmers in the region, cannot afford purchasing a new tractor and, therefore, prefer a used tractor of a lower price. In addition, the 2001 economic crisis in Turkey caused many farmers to sell the new tractor and replace it with a less expensive one. These factors made it possible for used tractors to have a better market in the region.

Farm operators prefer tractors with low fuel consumption and high power. These two factors are technical features influencing production costs of farm operations. A tractor with low fuel consumption decreases production costs and a tractor with higher power increases work efficiency. Together, these two

Economic and social factors	Mean	Std. deviation
Price of tractor	1.18	0.51
Brand of tractor	1.90	0.99
Having cab	2.32	1.17
Being a commonly used tractor in the region	2.34	1.08
Using similar tractor earlier	2.77	1.11
Desire of household members	3.00	1.25
Physical appearance of tractor	3.05	1.12
Tractor adds on mass media	3.18	1.39
Influence of neighbor farmers	3.59	1.20

Table 3 Economic and social factors influencing farmers' selection of tractor

	Value
Farm size (ha)	
The Smallest	3
The largest	110
Mean	16.66
Number of tractor	241
Power delivered by tractor (kW)	
The lowest	33
The highest	77
Mean	50.1

Table 4 Farm size, number of tractors, and power of tractor in research area

factors have positive effects on economic use of farm machinery and other resources.

Among technical features, power steering and double traction were ranked less important compared to other factors. The rank of power steering can be attributed to the cropping pattern in the region that requires seeding on rows, and farmers found it difficult to have control on their vehicle with power steering when seeding on the rows. The rank of double traction, on the other hand, can be attributed both to the high prices and farmers' unawareness of this kind of tractors.

Prices for farm machinery are an important factor for farm operators. As an economic rule, demand for goods and services should be supported by purchasing power. If farm operators have limited purchasing power for farm machinery, they can barely afford cheaper tractors while wealthy farmers can afford more expensive farm tractors. Therefore, price is a deciding factor on tractor selection.

As farm size increased, farm operators tended to purchase more powerful tractors. This finding of the study indicates that farmers consider their farm sizes when selecting the power of tractor.

From the findings of this study, it can be concluded that farm operators in the region seem likely to be reasonable on tractor selection; at least to the extent of their social and economic possibilities. However, they are in need of proper information and instructions which can be provided them by the technical personnel of the Ministry of Agriculture and Rural Affairs. In addition, dealers of farm machinery in the region should employ technical personnel who posses adequate knowledge and experience about tractors. If farmers are assisted in the choice of the correct tractors for their farm operations, they will probably decrease production costs and facilitate farm work.

Future research directions that arose from the findings of this study could be "determining economic loses of farmers by selecting the wrong tractor, or vice versa". Another future research focus might be to determine the influence of technical personnel of the Ministry of Agriculture and Rural Affairs on farmers' selection of proper tractors.

REFERENCES

Anonymous. 1999. Machinery Management. How to Select Machinery to Fit The Needs of Today's Farm Managers. John Deere Publishing, Almon-TIAC Building, Suite 140, 1300 19th Street, East Moline, IL 61244.

Anonymous. 2002 a. Tarim ve Koy Isleri Bakanligi, Tarimsal Uretim ve Gelistirme Genel Mudurlugu, 28.01.2002 tarih ve TAMD/TM-153-0155 sayili, "Arastirma, Gelistirme Stratejilerinin Belirlenmesi" Konulu Yazi, Ankara.

Anonymous. 2002 b. Kahramanmaras' in Tarimsal Yapisi. (http://www.tarim.gov.tr/yonetim/iller/K_Maras/tarimsal.htm)

Anonymous. 2002 c. Tarim Alet ve Makineleri 1998. (http://www.die.gov.tr/TURKISH/ISTATIS/Esg2/46MARAS/tarim9.htm)

Davis, J. A. 1971. Elementary Survey Analysis. Englewood Cliffs, NJ:Prentice-Hall.

Demirci, K. 1986. Buyuk Guclu Traktor ve Buyuk Is Kapasiteli Makinalarin Kullanilma Olanaklari. Tarimsal Mekanizasyon 10. Ulusal Kongresi Bildiri Kitabi, S.23-33, 5-7 Mayis, 1986. Adana.

Grisso, R. D., D. L. Morgan, G. J. Shropshire, and S. K. Rockwell. 1988. What Information Helps A Farmer Purchase A Tractor?. American Society of Agricultural Engineers. 4(3): 197-200.

Isik, A. 1988. Sulu Tarimda Kullanilan Mekanizasyon Araclarinin Optimum Makina ve Guc Secimine Yonelik Isletme Degerlerinin Belirlenmesi ve Uygun Secim Modellerinin Olusturulmasi Uzerinde Bir Arastirma (Doktora Tezi), CU Fen Bilimleri Enstitusu Tarimsal Mekanizasyon Anabilim Dali, 210 S., Adana.

Isik, A. 1996. Isletme Ozelliklerine Uygun Traktor Secimine Yonelik Uzman Sistem Gelistirilmesi Uzerine Bir Arastirma. 6. Uluslararasi Tarimsal Mekanizasyon ve Enerji Kongresi Bildiri Kitabi, S. 302-314, Ankara.

Liljedahl, J. B., P. K. Turnquist, D. W Smith., and M. Hoki. 1989. Tractors and Their Power Units. Fourth Edition. Van Nostrand Reinhold, New York.

Sabanci, A. and A. Aybek. 1990. Ceyhan Ilcesinin Tarimsal Mekanizasyon Ozellikleri ve Bu Ozellikler Arasi Iliskiler. 4. Uluslararasi Tarimsal Mekanizasyon ve Enerji Kongresi, Bildiri Kitabi, S.36-46, Adana.

Sabanci, A. and I. Akinci, 1994. Dunyada ve Turkiye'de Tarimsal Mekanizasyon Duzeyi ve Son Gelismeler. Tarimsal Mekanizasyon 15. Ulusal Kongresi Bildiri Kitabi, S. 404-415, Antalya.

Srivastava, A. K., C.E. Goering and R.P. Rohrback. 1993. Engineering Principles of Agricultural Machines. ASAE Textbook Number 6, ASAE 2950 Niles Road, St. Joseph, Michigan 49085-9665, USA.

Voelker, D. H. and P. Z. Orton. 1993. Cliffs Quick Review Statistics. Cliffs Notes Incorporated Lincoln, Nebraska, 68501. USA.

■■

Effect of Impeller Materials on Centrifugal Pump Characteristics

by
Bahattin Akdemir
Professor
Trakya University, Tekirdag Agricultural Faculty,
Department of Agricultural Machinery
59030 Tekirdag
TURKEY
bakdemir@tu.tzf.edu.tr

Birol Kayisoglu
Professor
Trakya University, Tekirdag Agricultural Faculty,
Department of Agricultural Machinery
59030 Tekirdag
TURKEY
bkayisoglu@tu.tzf.edu.tr

Senel Kocoglu
Agricultural Engineer (MSc)
Trakya University, Tekirdag Agricultural Faculty,
Department of Agricultural Machinery
59030 Tekirdag
TURKEY

Abstract

The purpose of this research was to reduce energy consumption by increasing the efficiency of centrifugal pumps with different impeller materials. The materials were cast iron, cast brass and cast iron coated with chemical polymer composite.

Reducing surface roughness caused an increase in pump efficiency and a decrease in power requirement. The power requirement of the pump coated with polymer composite was 9.11 % less than that of the cast iron pump.

Power requirement of the cast brass impeller was higher (1 %) than the cast iron pump for the open type pumps. Total head, pump efficiency and the flow rate of the cast brass impeller were higher than those of the cast iron impeller.

Introduction

Many factors affect centrifugal pump performance. These are specific speed, cavitation, net positive suction value, flow rate, static pressure head, dynamic pressure head and power. Another factor is surface roughness of the pump body and impeller. Relationship between these factors have been investigated by some researchers (Özerengin, 1972); (Ergin, 1979); (Baysal, 1975); (Edis et al, 1978); (Gökelim, 1976); (Karassik et al, 1985); (Tezer, 1978). The surface roughness of the pump impeller causes friction losses. Energy losses, cavitation probability and decreasing of the pump's efficiency can occur as a result of the friction resistance (Ida, 1965). Decrease in the pump efficiency means a higher power requirement for the pump's task.

The purpose of this research was to improve centrifugal pump efficiency by using impeller materials of different roughness. Two different types of centrifugal pumps were used in this research; closed type impeller, and open type impeller. Different materials such as cast iron manufactured impeller, cast brass and cast iron coated with polymer composite were used to obtain different surface roughness. Laboratory experiments were conducted according to the standard of the centrifugal pump performance experiments. Surface roughness and pump characteristics such as flow rate, speed (rpm) of the pump, total pressure head, required power, water power and efficiency were measured or calculated. Production cost of the impellers were also calculated and compared.

Materials

Centrifugal Pumps

The pump bodies were produced from cast iron. The shafts of the pumps were horizontal and bodies were snail types. The centrifugal pumps and impeller material types used in the research are given below.

Table 1 Technical specification of the impellers

	Closed type impeller	Open type impeller
Number of impeller	1	1
Number of vane	5	6
Outside diameter of impeller (mm)	246	190
Inside diameter of impeller (mm)	66	87
Impeller thickness (mm)	68	5
Vane wide (mm)	11	17.5
Shaft diameter (mm)	23	23

Table 2 Surface roughness of the impellers (µm)

	Closed type	Open type
Cast iron impeller	50	30
Cast brass impeller	40	4
Cast iron impeller coated with polymer composite	5	-

1. Centrifugal pumps with the closed impeller: cast iron impeller, cast brass impeller, cast iron impeller with coated polymer composite materials
2. Centrifugal pumps with open type impeller; cast iron impeller, brass impeller.

Technical specifications of the pumps and impellers are given in **Table 1**. Schematic view of the impeller and the pump body can be seen in **Figs. 1**, **2**, **3** and **4**.

Surfaces of the impeller and body were coated with Polymer Composite Material layers in 1mm thickness. Polymer Composite, used to decrease surface roughness on metals, is an epoxy, which, in effective form is forced with ceramic to increase resistance to wear and to decrease coefficient of friction. Polymer composite is applied by vacuum process, which reduces the possibility of microscopic air bubbles (Anonymous, 1994).

Pump Testing Apparatus

A schematic view of the pump testing experimental apparatus is shown in **Fig. 5**, which consists of a water pool, electric motor and a pump mounted on a fixed chassis with a rubber coupling 1 m above the water level in the pool. All the pipes of the system are made of iron. The pump outlet was connected through a short reduction pipe to pumping line, which had two elbows. A flow rate control vane and a pressure line manometer were mounted 8.32 m and 0.56 m, respectively, away from the pump outlet.

Methods

The impeller surface roughness was measured in the quality control laboratory of the producer firm using a profile-meter. The measurement processes were repeated if differences more than 2 %, among replications were noticed.

The experiments were performed according to the Turkish Centrifugal Pump Experiment Standards (Anonymous, 1990). Water at a temperature of +4 ºC was used in the experiments. Vaporization pressure (kPa), density (kg/m^3) and viscosity (m^2/s) of the water were determined, using table data, which are 0.0083 kPa, 1,000 kg/m^3 and 17.8

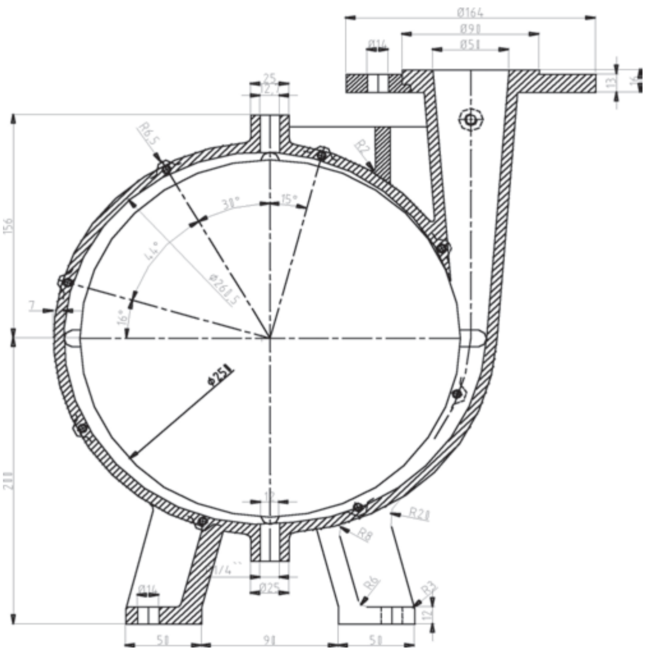


Fig. 1 Body of centrifugal pump with the closed impeller

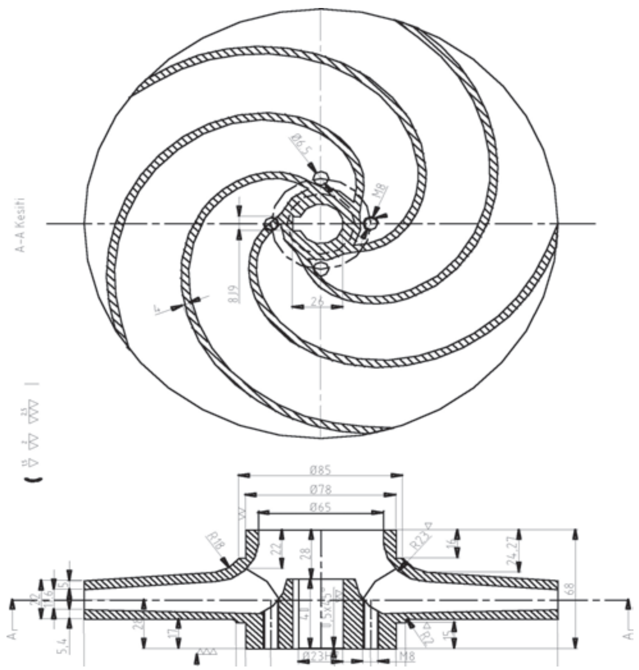


Fig. 2 Closed impeller

(m^2/s), respectively (Anonymous, 1990). The centrifugal pumps and the electrical motor speeds were measured by the electronic tachometer in three replications.

Since the volume of the pool must be large enough according to the centrifugal pump standards, the minimum filling time of the pool was 20 s for a 1 m^3 volume of the pool. Filling time was measured in three replications for each value of the total head obtained by adjusting the flow control vane.

The measured and calculated values, such as pump shaft speed, filling time for 1,000 liter, flow rate, brake power, suction pressure, pump pressure, total dynamic pressure head, water power and total pump efficiency were summarized in the tables.

Total pressure head was calculated from the total adopted values of suction and pressure line sections considering a reference line while the pump was working at adjusted conditions. Losses between the pressure manometer and pump outlet were added to the total pressure head because the pressure manometer was located at a certain distance away from the pump outlet in the experimental apparatus according to DIN 1944. If measuring points are not nearby the pump outlet and inlet or these are located on the suction and pressure pipe line, losses of the pipe and other pieces located between the measuring points and the pump must be added to the total pressure head (Silay, 1965). Total head was calculated from equation 1.

$H_m = H_s + H_{em} + H_b + H_{kb}$ ....(1)

where

H_m = Total head (m)

H_s = Static pressure head (m)

H_{em} = Suction vacuum pressure (m).

H_b = Dynamic head (m)

H_{kb} = Losses up to the pressure manometer (m).

Brake power of the electric motor was calculated by equation 2. The values of the ampere-meter, voltmeter and cosine Ø were read in three replications.

$N = 3^{1/2}\, U\, A\, \mathrm{Cos.}\, ø\, \eta$ ....(2)

where

N: Brake power (W)

$3^{1/2}$: Coefficient of three phase electric motor

Table 3 Summarized results for the enclosed type centrifugal pumps

Impeller type	Brake power (kW)	Total head (mss)	Flow rate (m^3/h)	Overall efficiency (%)
Cast iron impeller coated with polymer composite	8.628	42.38	33.65	0.450
Cast brass impeller	9.319	42.75	34.47	0.430
Cast iron impeller	9.415	42.51	34.62	0.426

Table 4 Summarized results for the open type pump characteristics

Impeller type	Brake power (kW)	Total head (mss)	Flow rate (m^3/h)	Overall efficiency (%)
Cast brass impeller	5.93	23.07	41.83	44.4
Cast iron impeller	5.87	22.61	34.33	36.0

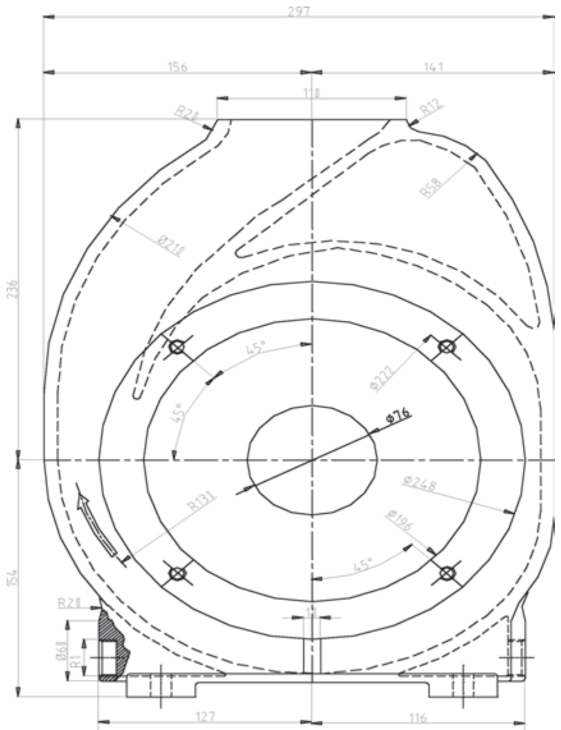


Fig. 2 Body of the centrifugal pump with open impeller

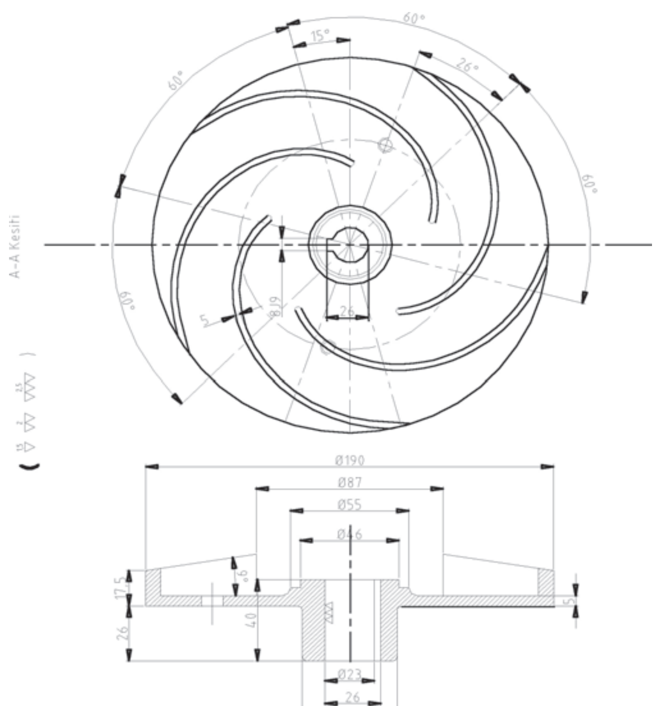


Fig. 4 Open impeller

Table 5 Production cost results for a centrifugal pump ($US)

Cast source	Closed type impellers			Open type impeller	
	Cast iron impeller	Brass impeller	Cast iron impeller coated with polymer composite	Cast iron impeller	Brass impeller
Casting	4.78	16.36	4.78	2.38	6.76
Labor	3.44	3.44	3.44	2.52	2.54
Coating	-	-	19.63	-	-
Total	8.22	19.80	27.85	4.90	9.30

U: Mean voltage (Volt)

A: Mean current (Ampere)

Cos. ø: Power factor

η: Efficiency of the electric motor

Determination of the electrical motor efficiency was realized by using electrical engine efficiency and load factor diagram.

Water power was calculated from equation 3.

$$N_c = \frac{Q..H_m \bullet \gamma}{75} \bullet 0.735 \text{ ....(3)}$$

N_c: Water power (kW)

Q: Flow rate (m^3/s)

H_m: Total head (m)

γ: Density of the water (1,000 kg/m^3 at +4 ºC)

Pump efficiency was calculated by equation 4 (Karassik et al, 1985).

$$\eta_p = \frac{N_c}{N_g} \text{ ....(4)}$$

η_p: Pump efficiency

N_c: Water power (kW)

N_g: Brake power (kW)

Manufacturing costs of the impellers were calculated for open and closed type impellers for a pump production of 5,000 units.

Costs of the pig and cast brass impeller included casting and labor costs. There was an additional cost of the polymer composite coating of the cast iron impeller.

Results and Discussions

Roughness of the Impeller Surfaces

The surface roughness for each impeller is given in **Table 2**.

The coating process reduced the surface roughness of the centrifugal pump with the closed type impeller. The best result of roughness was 5 µm obtained for the cast iron impeller coated with polymer composite. However, coating of the closed type impeller was very difficult. The range of the surface roughness of the cast iron impeller and the brass impeller for the two types of impeller varied widely, as it shown in **Table 2**.

Pump Characteristics

Results of the pump characteristics can be seen in the following tables and figures for centrifugal pumps with the closed and open type impeller.

The summary of the results is in **Table 3**.

The pump with impeller coated polymer composite was the most efficient (45 %) and its power requirement was the least at 8.62 kW.

There are no important differences between the closed impellers for total headand flow rate. But the efficiency and power requirement of the cast iron coated with polymer composite were better than others. The flow rate was reduced a little because of the reduction in the cross section area due to coating process.

Power requirement of the pump coated with the polymer composite was 9.11 % less than that of the pump with cast iron impeller, which showed the poorest performance in the experiments. The power requirement differences between the pump with coated polymer composite and the cast iron pump was 0.787 kW (1.07 HP). If the results are converted to energy and evaluated, the pump-coated polymer composite saves 0.878 kWh per hour.

Having evaluated the open type pump results and related graphics, the summary in **Table 4** may be given.

The pump with brass impeller was the most efficient pump (44.4 %) and its power requirement was 5.93 kW.

Total head, flow rate of the brass cast impeller were better than the cast iron impeller.

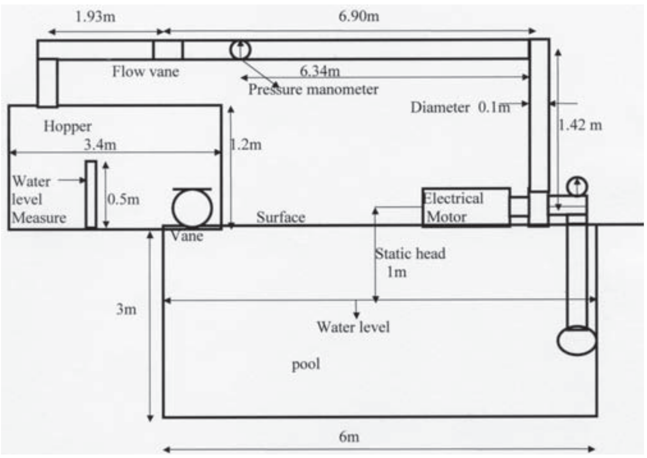


Fig. 5 Pump testing apparatus

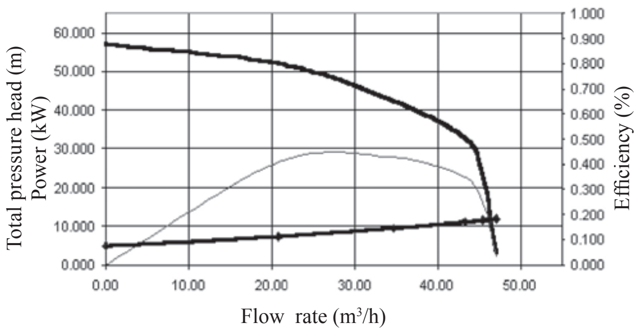


Fig. 6 Pump characteristics of the cast iron impeller

The differences of the total head, flow rate and overall efficiency between these two pumps were 0.46 m, 7.50 m^3/h and 8.4 %, respectively. Power requirement of the pump with the brass cast impeller was 1 % higher than that of the pump with cast iron impeller and the flow rate was higher.

Manufacturing Cost

Production costs of the centrifugal pumps with closed and open impeller are given in **Table 5**.

Cost of the closed type impeller coated polymer composite was higher than that of the others. A large proportion of the production cost was due to the chemical materials. Cost of this impeller was 338 % higher than the cost of centrifugal pumps with closed type cast iron impeller. The cost of closed type impeller coated polymer composite was also 40 % higher than that of the cast brass impeller.

Differences between the costs of the open types impellers were determined. Brass cast impeller cost was 4.40 US$ higher than that of the cast iron impeller.

Conclusions

The following conclusions may be drawn from this work:

1. Reduction of impeller surface roughness positively affected the pump efficiency and power requirement.
2. Power requirement of the polymer composite coated impeller was less (9.11 %) than the cast iron pump. Flow rate of the centrifugal pump coated with polymer composite was lower than that of the closed type pump because the pump dimensions were changed by the coating.
3. Closed type impeller coated with chemical polymer composite was the most effective pump in the laboratory tests. The coating process was difficult for the closed type impellers.
4. The coating process increased the pump-manufacturing cost.
5. The power requirement of the brass type impeller, whose surface was processed to decrease roughness, was higher (1 %) than that of the cast iron pump with the open type impeller. Total head, pump efficiency and flow rate were also higher than the cast iron pump.
6. The cast brass impeller was more efficient than the cast iron impeller because of the surface roughness of the cast brass was reduced by machining. Total pressure head and flow rate of the cast brass impeller were also higher than cast iron.

REFERENCES

Anonymous (1990). Centrifugal Pumps, Turkish Standards Institute-TSE 268 Turkish Standards Institute, Ankara

Anonymous (1994). Polymer Composite, Catalogue (ARC Compos-

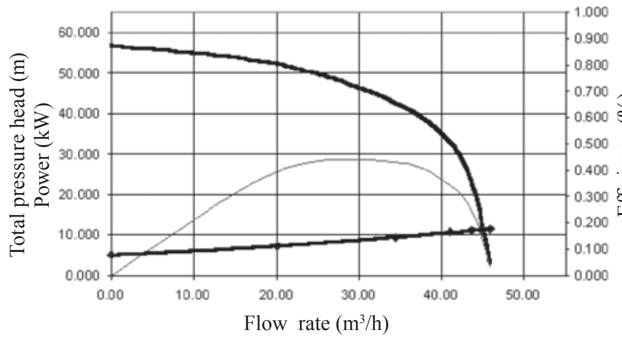


Fig. 7 Pump characteristics of the cast brass impeller

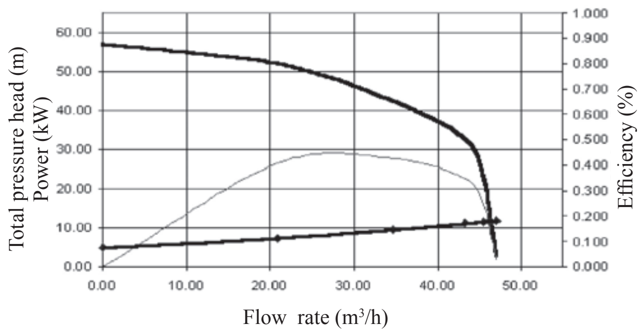


Fig. 8 Pump characteristics of close type, cast iron impeller coated with polymer composite materials

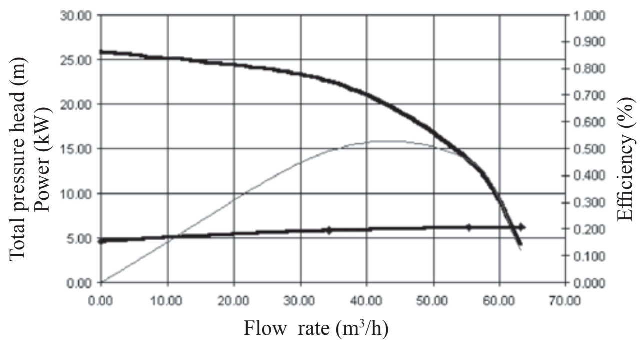


Fig. 9 Pump characteristics for open type pump with cast iron impeller

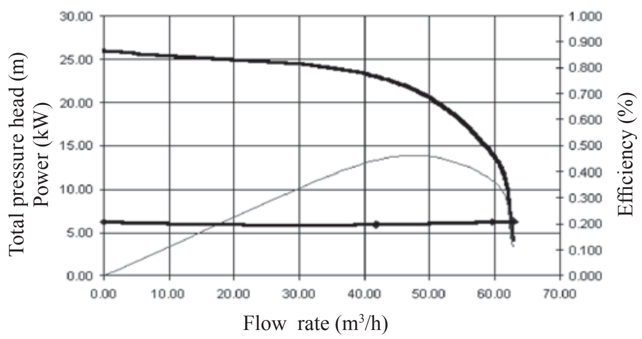


Fig. 10 Pump characteristics for open type, cast brass impeller pump

ites)
Baysal, K. (1975). Full Centrifugal Pumps (Calculations, Technical Drawing, Construction specifications), Istanbul Technical University, Istanbul
Edis, K., Tekin, Y., Petermann, P, (1978). Fluid Machines, Istanbul Technical University Engineering and Architectural Faculty, Istanbul
Ergin, A. (1979) Water Machines, Istanbul Technical University Mechanical Engineering Faculty, Istanbul
Gokelim,. A, T (1976). Pumps, Birsen Book Company, Istanbul.
Ida, T. (1965) The Effects Of Impeller Vane Roughness And Thickness On The Characteristics Of The Mixed-Flow Propeller Pump, Bulletin Of JSME No: 32, p:634-643.
Karassik, I., J., William,. C, Warren, W., H, K., Fraser, H., (1985), Pumps Hand Book, Worthingon Pump Inc. Joseph P. Musina Public Service Electric And Gas Company New Jersey Institute Of Technology Mc Graw-Hill Book Company, New York.
Özerengin, F (1972). Centrifugal and Axial Flow Pumps. Kurtulu_ Book Company, Istanbul.
Silay,. A (1965) Experiment of the centrifugal pumps, (VDI-Centrifugal Pumps Essentials, DIN 1944), Turkish Sugar Production Factory, No: 124, (1965) Ankara
Tezer, E (1978) Pump systems in Irrigation (Project, Selection and management methods), Cukurova University Agricultural Faculty, Adana.

■■

Performance Evaluation of a Safflower Harvester

by

Devanand Maski
Principal Investigator
J.S.S. Research Foundation,
S.J. College of Engineering,
Mysore 530 006, University of Mysore
INDIA

T. Guruswamy
Professor
College of Agricultural Engineering,
Raichur 584 101,
University of Agricultural Sciences, Dharwar
INDIA

Abstract

A self-propelled mini harvester was developed for harvesting safflower crop in India. The prototype safflower harvester consisted of a harvesting unit and power source mounted on a power tiller chassis. The harvesting unit included a power transmission unit, cutter bar assembly and conveyor assembly. A power transmission system for the harvesting unit was designed such that a cutting speed of 1.0 m/s could be obtained at the cutter bar. The machine was tested for harvesting safflower (S-144 variety) at an average forward speed of 1.0 km/h. The machine could harvest about 0.1 ha/h with a total field loss of 3.75 percent, which included post harvest, cutting and conveying losses. The unit cost of operation was US $ 11.60/ha, which is US $ 3.40/ha (29.31 percent) less than that of manual harvesting. The savings in harvesting time by the machine was 140 h/ha as compared to the manual method. The energy consumed in harvesting safflower crop by the harvester was 292.40 MJ/ha as compared to 40.26 MJ/ha manual harvesting.

Introduction

Karnataka is the second largest safflower (Carthamus tinctorius) growing state in India, next to Maharastra, with an area of about 258,000 ha and production of about 151,000 t (Anon, 2000). The districts of Northern Karnataka constitute the major safflower growing area in the state. The area under safflower cultivation has been increased considerably due to high economic value of the crop in the market and use of safflower oil for edible purposes by a majority of the people of the northern dry region of Karnataka.

Generally, farmers of this region harvest the safflower crop manually by using plain sickles. The crop is harvested in the early morning hours, when there is dew on the crop to prevent shattering loss as well as injury from plant spines to the labour. This method is not only time consuming but also labour intensive. Such labour intensive post harvest operations not only reduce the profit but also increase human drudgery. The delayed and time-consuming harvesting operation will expose the crop to the natural hazards like wind and rain.

Some researchers have developed small machines for harvesting cereals, pulses and oil seeds (Devnani and Pandey, 1981; Garg and Sharma, 1985 and Dutt and Prasad, 1993). Though these machines work satisfactorily for cereals like paddy and wheat, they pose problems for oil seeds like safflower. The bushy nature of the crop canopy, and other problems involved in manual harvesting, demands a need for the development of a machine for safflower harvesting. Keeping this in view, a self-propelled safflower-harvesting machine suitable for small Indian farmers was developed and its performance evaluated in the field.

Materials and Methods

In this section a brief description about the construction and functional parts of the harvester is presented. A systematic procedure for field evaluation of the machine and methods of estimating unit cost and energy involved in the harvesting is also described.

General Description of the Machine

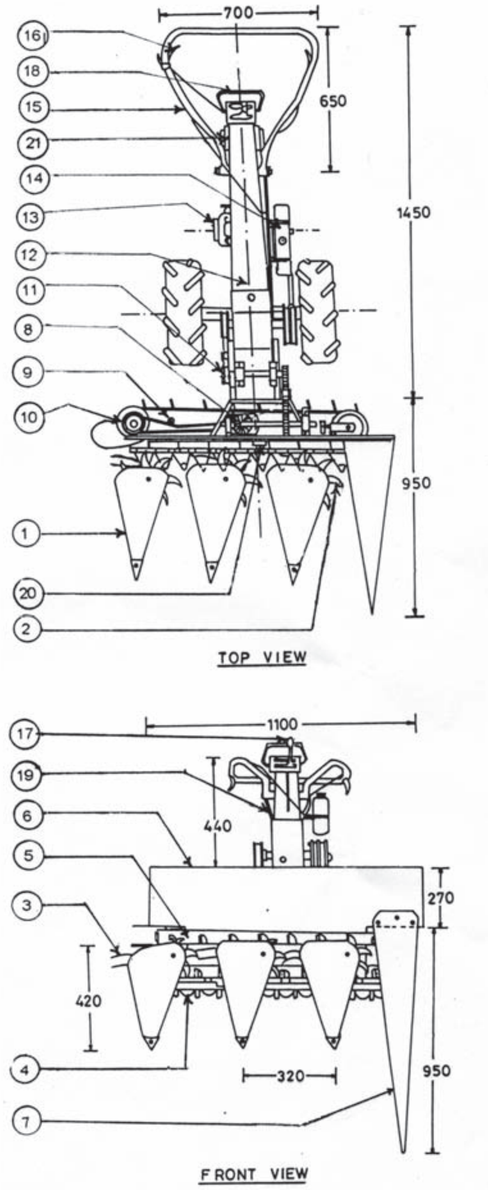
The main components of the developed safflower harvester were harvesting unit, power tiller chassis and power source. The harvesting unit was the main component of the machine. The main assemblies of the unit were crop holding platform, crop dividers, star wheels, press bars, cutter bar and conveyer belt. During the process of harvesting, the crop dividers guide the crop rows to the cutter bar assembly with the help of feeding star wheels. The crop was cut by the shearing action of the cutter bar assembly in which a number of serrated blades were moving against its shoes. The effective width of cutter bar was 1,000 mm. A crop holding platform was provided that was sufficiently large to hold the tall and bushy plants with the help of press bars while cutting and conveying. The crop divider provided at the right corner (viewed from front side) was modified for proper division of the harvested crop rows from that of un-harvested ones in field. The cut crop rows were conveyed to the left side of the machine by a conveyer belt system provided on the crop holding platform. The crop conveyer system was a canvas belt with push plates (provided at an angle of 30 degrees from the direction of motion) enclosed between two pulleys provided at both sides of the crop holding platform. Push plates on the conveyer belt acted as small individual plant conveying compartments to each branch of the plant and also provided power to the rotating star wheels. A depth control wheel at the rear side of the chassis helped in adjusting the length of crop cut from the ground level.

A power tiller chassis was selected for mounting the power source. The selection of this chassis was based on the fact that it provided a higher ground clearance for mounting the power source; it was light in weight, easily maneuverable and provided a transmission system to obtain different forward and reverse speeds. A 5.0 hp air-cooled diesel engine mounted at the rear side of the chassis provided power to the ground wheels as well as the cutting and conveying assemblies of the harvesting unit. The power transmission system consisted of a set of bevel gears, pulleys, chain sprocket and a pitman arm. The system was designed to obtain a cutter bar speed of 1.0 m/s, by eccentric arrangement, at a forward speed of 1.0 km/h. This was achieved with the help of horizontal and vertical shafts mounted on two pedestal bearings in front of the axle. Suitable chain and sprocket drive and bevel gear units were mounted on the shafts. An idling pulley was provided at the power transmission belt to engage or disengage power from source to the harvesting unit through the clutch provided at the operating handle. The overall length and gross weight of the machine was 2,400 mm and 340 kg, respectively. The drawing details of the safflower-harvesting machine are shown in **Fig. 1**.

Test Procedure for Field Evaluation

The machine was evaluated for harvesting safflower (S-144 variety) grown as sole crop under rain fed conditions at the Regional Research Station Farm, Raichur, Karnataka, India. The performance of machine harvesting was compared with manual harvesting. A plot size of 10.00 m x 25.00 m with five replications was selected for the evaluation of machine and manual harvesting. Four farm workers were engaged for manual harvesting. The different parameters of the test crop

Fig. 1 Proto-type safflower harvester



S. No.	PARTS
1	CROP DIVIDER
2	STAR WHEEL
3	PRESS BARS
4	CUTTER BAR ASSEMBLY
5	CONVEYER BELT
6	CROP HOLDING PLATFORM
7	LEFT-ROW CROP DIVIDER
8	BEVEL GEAR
9	IDLING PULLEY
10	BELT CONVEYER PULLEY
11	PEDESTAL BEARING
12	POWER TILLER CHASSIS
13	5 HP DIESEL ENGINE
14	FUEL TANK
15	OPERATOR'S HANDLE
16	STEERING CLUTCH
17	GEAR SHIFT LEAVER
18	POWER TRANSMISSION CLUTCH
19	IDLING PULLEY OPERATE LEAVER
20	ECCENTRIC TO CUTTER BAR
21	BALANCING COUNTER WEIGHT

were recorded and are presented in the **Table 1**. The machine and operational variables for harvesting were selected according to Datt and Prasad (1993). The parameters used for the field evaluation are presented in **Table 2**. During testing, the different observations such as area covered (effective field capacity), forward speed, pre-harvest losses, cutting and conveying losses (windrowing losses), fuel consumption, height of stubble after harvest and the area harvested by women workers were recorded and average harvest per worker was computed.

Cost and Energy Appraisals of Harvesting Methods

The cost and energy consumed for harvesting safflower by the machine and manual methods were analyzed. The unit cost of operation of the machine was calculated by standard procedure (ISI 9164, 1979). For the calculation, the manufacturing cost of the harvester (US $ 1,400.00 which is equivalent to Indian Rupees 70,000.00) and the assumptions of useful life (10 years), annual usage (750 h), interest on investment (18.00 percent of the initial investment) and cost of diesel (US $ 0.40/L) were taken into account. The cost of operation included fixed (US $ 0.41/h) and operational costs (US $ 0.75/h). The fixed cost included the sum of cost of power tiller chassis with a 5.0 hp diesel engine and a harvesting unit (US $ 1,400.00). The operating cost was calculated by assuming operating cost of US $ 1.20 per day at 8 hours of work. The unit cost of operation for manual harvesting was calculated by assuming the prevailing wages of US $ 0.80 per day for 8 hours of work. The energy consumed by the machine was calculated based on the actual fuel consumption and that of the manual harvesting on the assumption of the average power of a man.

Results and Discussion

The prototype mini safflower harvester was tested and evaluated for harvesting safflower (S-144 variety) and the performance of the machine was compared with that of manual harvesting.

Effective Field Capacity and Fuel Consumption

The effective field capacity of the machine and manual harvesting is presented in **Table 3** and **Table 4**, respectively. This indicates that the area covered by the machine and manual harvesting was 1,000.00 m^2/h (0.1 ha/h) and 66.67 m^2/h (6.67 x 10^{-3} ha/h), respectively. The time required to harvest the crop by the machine was 10.00 h/ha and that of manual was 150.00 h/ha. This implies that the harvesting time required by the machine was 15 times less than the manual harvesting. The fuel consumption by the machine for harvesting was not more than 0.8 L/h, which is within the limit for safe field operation (Dutt and Prasad, 1993).

Field Losses in Harvesting Methods

The different field losses observed for the machine were post harvest losses (5.00 kg/ha), cutting losses (15.15 kg/ha) and conveyance losses (3.75 kg/ha). Among the different losses, the maximum loss of 1.37 percent was observed during cutting of the crop (**Table 3**). This may be due to the fact that the dried seed capsules of the crop get sheared off from the branches while cutting by knife section of the cutter bar. The corresponding losses for manual harvesting were 5.00 kg/ha, 2.00 kg/ha and 0.00 kg/ha, respectively (**Table 4**). The losses observed for the machine seem to be higher (nearly 241.43 percent) as compared to that of manual harvesting. However, these losses were within the limit for such machines (Dutt and Prasad, 1993).

Cost and Energy Appraisals

The details of the cost and energy calculations for the machine and manual harvesting are shown below.

a. Cost appraisal

i. Machine Harvesting

Fixed cost = US $ 0.41/h

Operating cost = US $ 0.75/h

Effective field capacity = 10 h/ha

Total cost of operation of the harvester = 1.16 US $/h

Total cost of operation of the harvester = 1.16 US $/h x 10 h/ha = 11.60 US $/ha

ii. Manual Harvesting

Workers wages per 8 h = US $ 0.80

Effective field capacity = 150 h/ha

Table 1 Crop parameters

Parameter	Values
Test crop	Safflower
Variety	S-144
Rain fed/Irrigated	Rain fed
Normal period of maturity, days	135
Plant height, mm	836.00 (770.00-870.00)
Plant population. No./m	13.50 (10.00-17.00)
Row to row spacing, mm	450.00
Branches per plant, No.	15.20 (10.00-18.00)
Capsules per branch, No.	4.40 (3.00-6.00)
Plant stem dia. at the cutting height, mm	9.75 (9.00-11.50)
Moisture content of the stem, percent (db)	28.31
Moisture content of the grain, percent (db)	8.08
1,000 grain weight, gm	50.13
Average grain yield, kg/ha	1,096.00

Note: The values given in the parenthesis are minimum and maximum values

Cost of manual harvesting = (0.80/8) US $/h = 0.10 US $/h

Cost of manual harvesting = 0.10 US $/h x 150 h/ha = 15.00 US $/ha

b. Energy Appraisal

i. Machine Harvesting

Fuel consumption = 0.8 L/ha

Effective field capacity = 10.00 h/ha

Fuel consumption = (0.8 L/h) x (0.86 kg/L) x (10 h/ha) = 6.88 kg/ha

Calorific value of Diesel = 42,500 kJ/kg

Energy value of Diesel = 6.88 kg/ha (42,500 kJ/kg) = 292.40 MJ/ha

ii. Manual Harvesting

Average power of a man = 74.56 x 10^{-3} kW

Energy required for manual harvesting = 74.56 x 10^{-3} kW x 150 h/ha =11.184 kW h/ha

Energy required for manual harvesting = 40.26 MJ/ha

The cost and energy consumed by the machine and manual harvesting of safflower crop is shown in Table 5. The unit cost of operation for the harvester was US $ 11.60/ha (US $ 1.16/h) and that of manual harvesting was US $ 15.00/ha (US $ 0.10/h). This indicated that the machine harvesting could save US $ 3.40/ha as compared to manual method. The energy consumed in harvesting safflower crop by the harvester was calculated to be 292.40 MJ/ha as compared to manual harvesting of 40.26 MJ/ha. The higher energy consumption by the machine may be due to loss of power at the different power transmission units.

Conclusions

The developed harvester was tested and evaluated for harvesting safflower and was compared with manual harvesting as practiced by the farmers of Northern Karnataka, India. The test results indicated that the machine could harvest 0.1 ha/h (10 h/ha) as compared to 6.67 x 10^{-3} ha/h (150 h/ha) by manual harvesting. The total field losses observed for machine were 3.75 percent as compared to 1.07 percent by manual harvesting. The unit cost of safflower harvesting by the machine was US $ 11.60/ha and that of manual harvesting was US $ 15.00/ha. The machine could save US $ 3.40/ha in unit cost of operation and 140 h of time as compared to manual harvesting. The energy consumed by the harvester was 7.26 times more than the manual harvesting for safflower crop.

REFERENCES

Anonymus, 2000. Agricultural situation in India. December, XLXII (4): 32

Devanand Maski and G. Venkatesh, 1994. Development and evaluation of power reaper. Unpublished B.Tech. (Ag. Engg.) thesis, University of Agril. Sciences, Dharwad.

Devanani, R. S. and M. M. Pandey, 1981. Evaluation of field performance of reaper binder for harvesting of wheat crop. Journal of Agricultural Engineering, XVIII (1): 97-100.

Dutt, P. and J. Prasad, 1993. Development and evaluation of self propelled vertical conveyor reaper for safflower crop. XXVIII Annual Convention of ISAE held at Central Institute of Agricultural Engineering, Bhopal, India.

Garg, I. K. and V. K. Sharma, 1985. Improved equipment for field operation of wheat and paddy crops. Indian Farming, 34 (11): 23-26.

ISI 9164, 1979. Indian Standard-guide for estimating cost of farm machinery operation. Indian Standard Institution, New Delhi.

■■

Table 2 Machine and operational parameters

Parameter	Values
Average forward speed, km/h	1.00
Effective cutter bar width, mm	1,000.00
Length of cutter bar, mm	1,100.00
Effective working width, mm	960.00

Table 3 Field performance results of harvester

Sl. No.	Performance parameters	Test results
1.a	Effective field capacity, m²/h	1,000.00
1.b	Effective field capacity, ha/h	0.10
2.	Fuel consumption, L/h	0.80
3.	Losses, kg/ha	
	i. Post harvest losses	5.00 (0.85)
	ii. Cutting losses	15.15 (1.37)
	iii. Conveying losses	3.75 (1.53)
	iv. Total losses	23.90 (3.75)
4.	Stubble height, mm	89.00

Note: The values given in the parenthesis indicate the losses in percent

Table 4 Test results of manual harvesting

Sl. No.	Performance parameters	Test results
1.a	Effective field capacity, m²/h	66.67
1.b	Effective field capacity, ha/h	6.67 x 10^{-3}
2.	Losses, kg/ha	
	i. Post harvest losses	5.00 (0.35)
	ii. Cutting losses	2.00 (0.72)
	iii. Total losses	7.00 (1.07)
3.	Stubble height, mm	69.00

Table 5 Cost and energy economics of machine and manual harvesting

Sl. No.	Performance parameters	Method of harvesting	
		Machine	Manual
1.a	Unit cost of operation, US $/h	1.16	0.10
1.b	Unit cost of operation, US $/ha	11.60	15.00
2.	Harvesting time, h/ha	10.00	150.00
3.	Harvesting energy, MJ/ha	292.40	40.26

Semi-Automatic VRT-Based Fertilization System Utilizing GPS

by

Moustafa A. Fadel
Assistant Professor of Agricultural Engineering
Arid-land Agriculture Dept.,
The United Arab Emirates University,
UAE, Al-Ain 17555
UAE
mfadel@uaeu.ac.ae

Ahmed El-Mowafy
Soil Specialist,
Arid-land Agriculture,
Arid-land Agriculture Dept.,
The United Arab Emirates University,
UAE

Abdul Elghaffar Jomaa
Public Works Dept.,
Faculty of Engineering,
Ain Shams University,
UAE

Abstract

Precision farming is one of the most growing arenas in the agricultural engineering field. Employing real-time GPS positioning methods, made it easy to build accurately guided machines. On the other hand, environmental concerns made it necessary to apply Variable Rate Treatment (VRT) concept in fertilization.

Precise fertilizer application is used widely where fully automatic systems are extensively presented commercially. In this research, a new semi-automatic system is designed and developed locally. The proposed system employs a real time GPS positioning system to guide a tractor mounted rotary spreader to apply phosphate to the field. In order to estimate soil requirements, the field was divided into a 50-meter mesh grid and soil samples were collected from eight GPS defined locations. Soil analysis results were mapped and studied to determine the needed amount of Calcium Super Phosphate to be added per hectare and a prescription map was developed. In order to evaluate system performance and its feasibility, soil chemical analyses of the same GPS defined locations were made after applying the fertilizers using the designed system. It was noticed that assessment of VRT-based systems is clearly stated anywhere in the literature. Different methods of performance assessment are presented in this research. The developed system was tested and evaluated in Al-Oha experimental farm, UAE University.

Introduction

Variable rate treatment is one of the most promising technologies in the agricultural systems arena for the surrounding environment, in addition to its economical feasibility. The concept itself is based on the belief that the field cannot be treated as one unit because of the variation among its finite areas. Fully automatic granular fertilizer broadcasting systems are widely available in most of the developed countries. In this research, a semi-automatic GPS-guided system is designed, built and tested. A novel procedure is presented to evaluate over all performance of the investigated system and could be extended to other VRT-based systems.

Bullock et al (2002) stated that many mechanized crop producers and agribusinesses are fascinated with precision agriculture technology, but adoption has lagged behind the expectations. Among the reasons for slow adoption of precision agriculture technology is that initial users focused excessively on in-field benefits from variable-rate fertilizer application using regional average fertilizer recommendations. Precision agriculture is spatial information technology applied to agriculture. The technologies include global position systems (GPS), geographic information systems (GHS), yield monitoring sensors, and computer controlled within field variable rate application (VRA) equipment.

ASAE standard (1999) was used to evaluate uniformity distribution of granular broadcast spreaders in one direction. The evaluation process had two considerable bases. It evaluated the uniformity distribution compared to machine path and compared readings to its average. It is crucial to evaluate the whole GPS-guided Variable rate fertilizer applicator to judge the feasibility of using it. In this research, two evaluation indexes were presented to assess performance of the VRA system as a function of distribution uniformity. The resulted indices would not be possible without refereeing to geostatistics studies

Literature Review

Many research papers discussed the issue of evaluating rotary granular fertilizer applicators guided with the ASAE standard (1999), where standard deviation is used to calculate distribution uniformity across the swath. However, this procedure cannot be extended to cover evaluation of the spatial data in 3D pattern. Yang et al (2001) mentioned that variable rate fertilizer application has the potential to improve fertilizer use efficiency, increase economic return and reduce environmental impact. They used the grid soil sampling method for assessing variability in soil fertility and provided the basis for variable rate fertilizer recommendations. They compared yield under uniform and variable rate treatment. When they studied the effect of variable rate application on yield variability, they concluded that the variable rate treatment had the lowest coefficients of variation in 5 of 6 blocks. Fulton et al (2001) investigated the accuracy of a variable rate fertilizer applicator. They collected the spread fertilizer using 13 x 13 matrix of collection pans to gather material spread by a spinner spreader truck. The results showed that spread variability existed with spinner spreaders. Coefficients of variations above 20 % were calculated for the average transverse spread patterns.

Bullock et al (2002) stated that global positioning systems (GPS) and sensors are turning the data-poor agricultural production sector into a data-rich environment. Farmers have always known that crop yields vary spatially. But, until the early 1990's, the technology of commercial farm equipment did not permit much in the way of spatial management. Also, gathering data on spatial variability of yields or farmland characteristics for the purpose of fine-tuning management was too expensive. Genton and Gorsich (2002) mentioned that kriging is a widely used method of spatial interpolation, particularly in earth and environmental sciences. It is based on the variogram or the covariogram; two functions that describe the spatial dependence. A reliable estimation of the latter is therefore crucial. They suggested a nonparametric variogram and covariogram estimation with Fourier-Bessel matrices.

VRT-Based Systems

Lida et al (2001) constructed a prototype of variable rate granular applicator for paddy field to apply Nitrogen fertilizer. They mentioned that over fertilization is a potential source of pollution in the form of Ammonia, Nitrate and Nitrite, which may pose a hazard to human health. Therefore, a contemporary issue is how to give an effective dose at the accurate position and right time for optimum growth of crops while preserving the environment without causing economic losses. They added that, during the top-dressing operation, the field with variable rate application consumed 12.8 % less of NK fertilizer than that of the uniform rate application.

Bakhsh et al (2000) stated (US-EPA, 1995) that the United States Environmental Protection Agency identified the agricultural sector as one of the major contributors to soil and water pollution. They concluded that a better understanding of yield variability across the field could improve management practices by including spatial information about the availability of soil water and nutrient status of the various field units.

The standard deviation refers to the mean as a reference value; therefore, it may be used to quantify the variability of soil fertility as stated by Jin and Jiang (2002). On the other hand, using it to assess VRT-

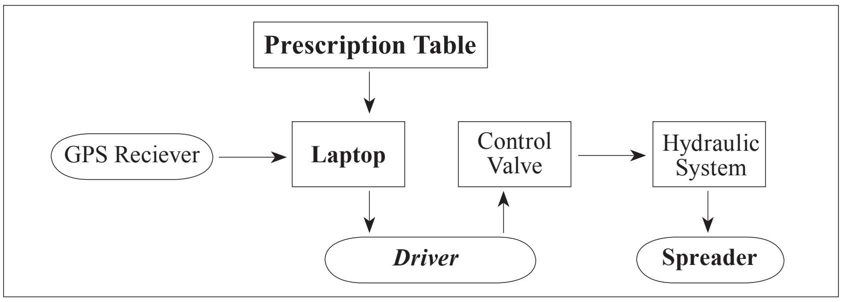


Fig. 1 System diagram

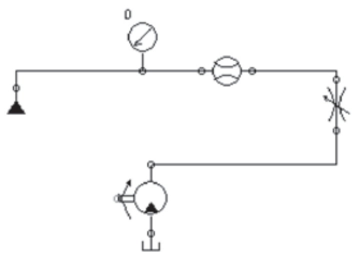


Fig. 2 The hydraulic system

based system performance would not be realistic. System assessment requires the referred value to be the targeted nutrient level.

Fulton et al (2001) stated that one of the means to measure and characterize application accuracy is computing the coefficient of variance (CV). The coefficient of variance provides a quantification of spread variation and accuracy. Low CVs indicate a more uniform spread distribution with 5 % to 10 % being a desired range for spinner disc spreaders. They added that, many factors affect fertilizer distribution and application accuracy, such as systematic errors associated with machine calibration and metering efficiency. However, Sogaard and Kiekegaadrd (1994) reported that CV's could be more in the range of 15 % to 20 % under field-testing. These higher CV's are probably due to rougher surfaces experienced under field conditions.

Parish (1991) reported CVs in the upper 20's to the lower 30's in some test cases with these high variations resulting from terrain irregularities. They added that, ASAE standard Procedure for Measuring Distribution Uniformity and Calibrating Granular Broadcast Spreaders (ASAE S431.2, 1997) provides a uniform procedure for testing, assessing the performance, and reporting the results of broadcast spreaders. It specifies test setup, collection devices, test procedures, effective swath width, and determination of the proper testing application rates. When using the outlined procedure, the results provide a quantification of application accuracy and possible spread pattern deviations. However, this standard does not cover the testing of broadcast spreaders with VRT.

Variography

Pringle et al (2002) assessed the opportunity for site-specific crop management in a field using yield monitor data. They stated that, the spatial variation observed in yield maps has convinced many researchers and farmers that uniform management of controllable crop inputs, the default practice of modern technology, may not be appropriate for all circumstances. Yield maps visually confirm what most farmers have always suspected about uniform management practices: some parts of their fields are oversupplied with inputs, while others are probably under supplied.

They added that the CV is non-spatial and therefore potentially misleading when dealing with different sized areas. They quoted Perrier and Wilding (1986) in saying that the semivariogram is a common assessment of yield variation. It is popular because it shows how variation changes through space.

Royale (1980) discussed the theory behind variograms. He defined it as one-half of the variance of the differences in sample grades between points separated by distance. Chiles and Delfiner (1999) mentioned that the variogram, unlike the covariance, does not require the knowledge of the mean. In practice, the mean is not known and has to be estimated from the data, which introduces a bias. They formulated the sample variogram as follows (Herzfeld, 2002):

$$\gamma(h) = \frac{1}{2N_h}\sum_{i=1}^{N_h}\left[g_i - g_{i+h}\right]^2 , \text{ ....(1)}$$

where

γ is variogram value, and

N_h is the count of pairs of points separated by the lag h.

They added that variogram may be calculated for different samples directions to create a more realistic portrait of the studied location. Vogel et al (2001) used semivariogram to determine omni directional, lateral, and longitudinal correlation distances for saturated infiltration on native warm season grass and the winter wheat watersheds. They quoted (Deutch and Journel, 1998) that; the semivariogram measures the average degree of dissimilarity between an unsampled value and a nearby data value.

Fig. 3 System control in front of the driver

Fig. 4 The semi-automatic VRT spreader

Materials and Methods

Developing the GPS-Guided VRT System

A semi-automatic real time GPS-guided, VRT-based system was developed locally. A 75 HP Fiat tractor was used to vehicle and energize system components where traditional hydraulic resources of the tractor were used as a power source to power a rotary spreader. System operation depended on using GPS sensors to precisely locate the vehicle's coordinate in the field and using a specially developed prescription table to add the prescribed amount of fertilizer in the associated location. To map P_2O_5 level in an experimental field with 50-meter mesh grid, eight soil samples were collected from GPS-identified sites in the field. The prescription table was developed as a result of knowing nutrient level in the field's different plots and next crop requirements. Rhodes was the regular forage crop on the farm. A laptop received coordinates information from a GPS unit where it was displayed and recorded. The driver followed the instructions on the laptop to change hydraulic valve settings to change hydraulic motor RPM accordingly. The spreader was calibrated according to ASAE Standard 341.3 (1999) and the overall system was calibrated. The calibration of the overall system was performed to develop the relationship between control valve setting and the broadcasting rate. A color code of the valve settings was developed as a result of both system calibration and prescription table for the three presumably homogenous zones. The developed color code is a simple control guide to fit to the driver's educational profile. According to soil sample analysis, the field was divided into three, presumably, homogenous areas. Corresponding fertilizer application rates were calculated according to technical recommendations and soil analysis results. The Green, Red, Blue (G, R, and B) code was shown in the control valve area in front of the driver.

As shown in **Fig. 1**, coordinate information flowed from the GPS receiver to the laptop, which displayed it in front of the driver. According to the prescription table and the color code of valve settings, the software advised the driver of what valve setting was needed in this specific location as a color message. When the driver changed a valve setting to the recommended one, hydraulic motor speed changed along with spreader RPM and broadcasting rate.

Using DGPS and RTK Techniques

The DGPS approach used corrections of the code measurements computed at the base (reference station) to eliminate similar correlated measurement errors at the rover. This included satellite clock biases and orbital errors as well as atmospheric (ionosphere and troposphere) errors. The corrections are combined and formulated as range corrections, which are estimated as the difference between the measured and the true satellite-to-receiver ranges, where the latter are computed from the known coordinates of the base station and the observed satellites. The base corrections are transmitted to the rover through data links. A common standard for sending these corrections is the RTCM format, which also includes information about reference station parameters and satellite health. A national system of reference stations transmitting code-measurement corrections via beacon transmitters is widely used in most countries, mainly along shores, such that the user would only need a beacon receiver attached to his GPS receiver, without worrying about establishing his own base station.

On the other hand, the RTK positioning technique uses either phase measurements or their corrections sent from the base to determine rover positions accurate to the cm level (Langley, 1998 and El-Mowafy,

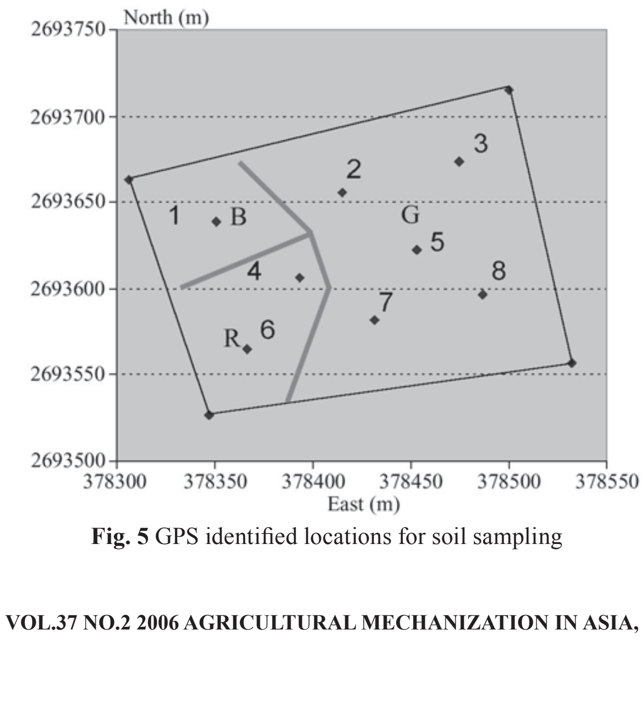


Fig. 5 GPS identified locations for soil sampling

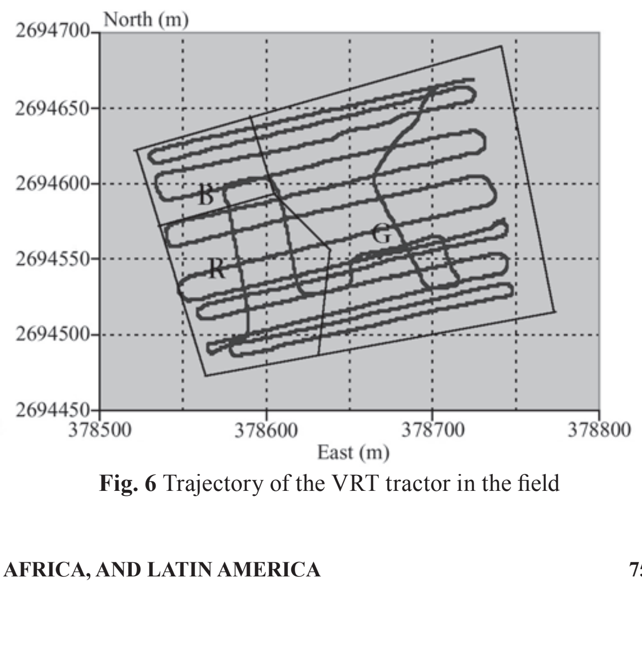


Fig. 6 Trajectory of the VRT tractor in the field

2000). Due to data latency, which is the time taken to gather and send the data from the reference to the rover, the corrections are sent instead of the raw measurements of the base. This is because of the fact that the corrections change slowly with time while the raw measurements change rapidly. In addition, due to latency, a method of predicting the phase corrections at the exact instant of measurement of collection at the rover should be employed, which should take into consideration the expected type of rover dynamics. From the known position of the base station, its phase measurements can be constructed, and after solving for the carrier phase ambiguities On-The-Fly (OTF), a model similar to that of code measurements, can be used to determine the coordinates of the rover receiver.

Guiding the tractor along a predefined path for tasks such as parallel swathing and to prevent it from either leaving areas uncovered or over-fertilizing some areas was also possible since positions were determined in real time. The software compared the current and target locations, and the difference in distance (off-course distance) could be displayed to the driver, as well as the direction to follow to reach the correct location. This feature was performed based on computation of the azimuth between the two positions from their coordinates. Thus, on-line guidance by GPS guarantees proper fertilization of all needed spots according to their actual needs. In addition, if the fertilization process had to be continued for a second day, the stored GPS positions when drawn on the field map would show the driver the exact area still to be fertilized. Similar arguments are also valid for the herbicide and pesticide process.

Hydraulic System

A simple hydraulic system was designed and installed on the tractor using the available hydraulic resources in the tractor. As shown in **Fig. 2**, the system consisted of flow and pressure meters, flow control valve and low speed hydraulic motor. Due to temperature concerns in this part of the world where ambient temperature exceeds 50 ºC, oil temperature before and after flow control valve was monitored using two thermometers. A Praker Haniffen M030 gerotor drives the calibrated rotary broadcasting spreader.

The angle between motor shaft and the spreader drive shaft exceeded 20º when spreader was lifted to the upper level of the hydraulic hitching mechanism. A 2-universal joint shaft was used to connect the two shafts together.

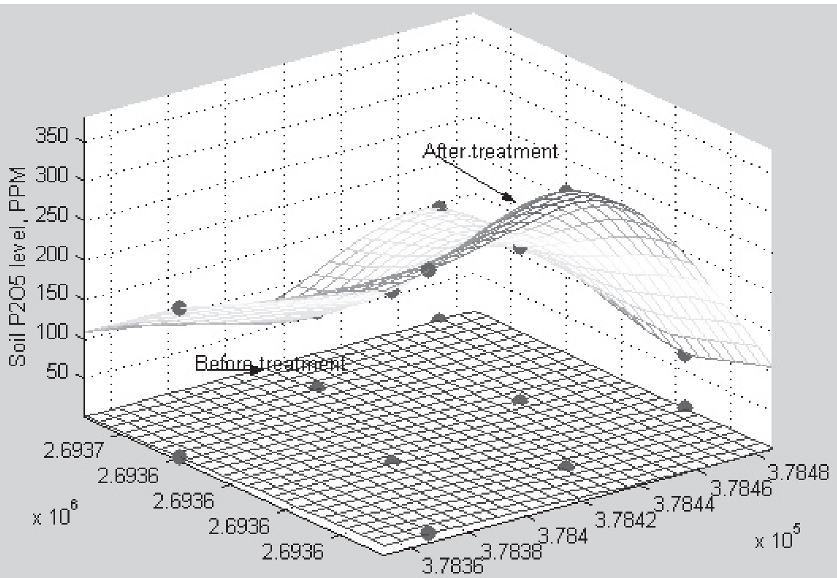


Fig. 7 P_2O_5 levels in the field before and after treatment

Results and Discussion

Testing of the Developed System

The experimental field is a part of Al-Oha farm, a research facility of the UAE University. Testing of the system was carried out in an open area of approximately 8.25 acres (33,000 m^2). The test area was rehabilitated sandy land prepared for cultivation and surrounded by a belt of high trees for its four sides. The positions of the eight samples, as well as the test area boundaries, were determined using a handheld GPS receiver (Garmin 48) (**Fig. 5**).

Vehicle path way was recorded as plotted in **Fig. 6**.

Due to its vital importance in arid lands, super phosphate was the focus of this research where Calcium Super Phosphate is the phosphate source. To evaluate P_2O_5 level in the field before fertilization, eight soil samples were collected from eight identified locations in an 8.25 acre field as shown in **Fig. 5**. The field was treated according to Rhodes grass fertilizers recommendations. Points of approximately equal P_2O_5 levels were given the same mark (G, B, or R), where each group was recognized as a homogenous zone to simplify the control process. The resulted P_2O_5 levels were used to produce an interpolation of the whole field mapping of P_2O_5 as shown in **Fig. 7**.

P_2O_5 analysis before and after treatment was plotted in **Fig. 7**. It is clear that, P_2O_5 changed in the field to some extend. In some parts there was an over dosage and in the other not enough fertilizer was applied. Nutrient variability in the field is a major concern when system performance to get evaluated. Other performance parameters should be considered such as accuracy that indicates how successful it was to add the right amount of fertilizer in the corresponding location.

For this specific research, CV values for P_2O_5 levels in the field before and after treatment were 86.66 and 51.29 respectively. That means, regardless the targeted level satisfaction, the system improved uniformity of P_2O_5 levels in the field by 60 %.

CV was calculated for both cases before and after treatment as mentioned in (ASAE 1999).

$$\text{Mean} = X = \sum\left(\frac{X_i}{N}\right) \text{, ...(2)}$$

Standard Devision = SD =

$$\sqrt{\frac{\sum(X - X_i)^2}{N-1}} \text{, and ....(3)}$$

$$CV = \frac{SD \times 100}{X} \text{, ...(4)}$$

where

X is arithmetic mean,

Xi is nutrient (P_2O_5) level in a GPS-identified location, ppm, and

N is number of GPS-identified locations.

Figures 8 and **9** display a different way of evaluating the VRT-based system. Semi-Variograms represents the variability of P_2O_5 levels in the field in two directions. East-West and North-South variability are shown. Semi-variogram is very important because it shows haw variation changes through space. It can be concluded that, in this specific field, variation in P_2O_5 was higher in the East-West direction than it was in the North-South direction. Using the system did not change the situation a lot in this criterion.

A variable rate applicator, with GPS guidance, was designed and built locally. The semi-automatic system depended on the driver to use the software recommendations to take a specific action and change control valve setting to change application rate to suit a specific site. Driver training allowed him to improve his time of response to deal with the prescription table. This human factor could cause a great deterioration of system performance if the driver is not well trained or is tired. This design saves money for the farmers who are not able to invest more money in such a VRT-based system. On the other hand, third world technological infrastructure does not help farm machinery designers or manufacturers to use ultimate technology. The performance of the developed system improved the uniformity of P_2O_5 presence in the field. Testing procedures of the overall performance should be established in order to quantify system quality and make it easier to compare between different systems working under different conditions.

REFERENCES

ASAE- American Society of Agricultural Engineers.1996. Procedure for measuring distribution uniformity and calibrating granular broadcast spreader. ASAE Standards. St. Joseph, p 3.

ASAE S341.2. 1997. ASAE Standards, 44th ED. Procedure for measuring distribution uniformity and calibrating granular broadcast spreader. ASAE St. Joseph, MI.

ASAE,1999. Procedure for Measuring Distribution Uniformity and Calibrating Granular Broadcast Spreaders. ASAE S341.3. American Society of Agricultural Engineering Standards.

Bakhsh, A., D. .B Jaynes, T. S. Colvin and R. S. Kanwar, 2000. Spatio-Temporal analysis of yield variability for a corn-soybean field in Iowa. Trans. of ASAE. Vol. 43: 31-38.

Bullock, D. S., J. L. DeBoer and S. M. Swinton, 2002. Adding value to spatially managed inputs by understanding site-specific yield response. Agricultural Economics, 27 (2002), pp. 233-245. Elsevier Science B.V.

Chiles, J. P. and P. Delfiner, 1999. Geostatistics Modeling Spatial Uncertainty. Wiley Series in

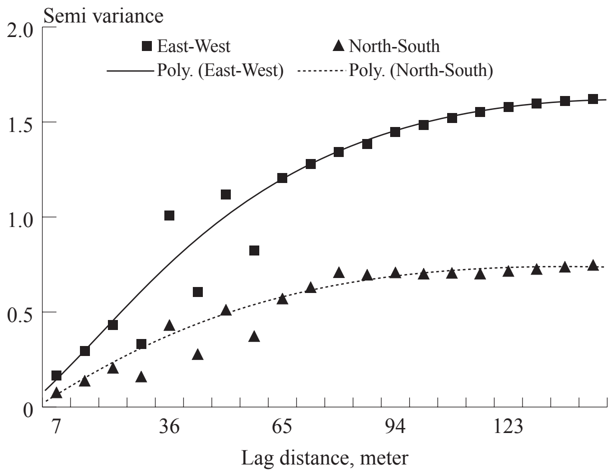


Fig. 8 Semi-variogram of P_2O_5 levels before treatment

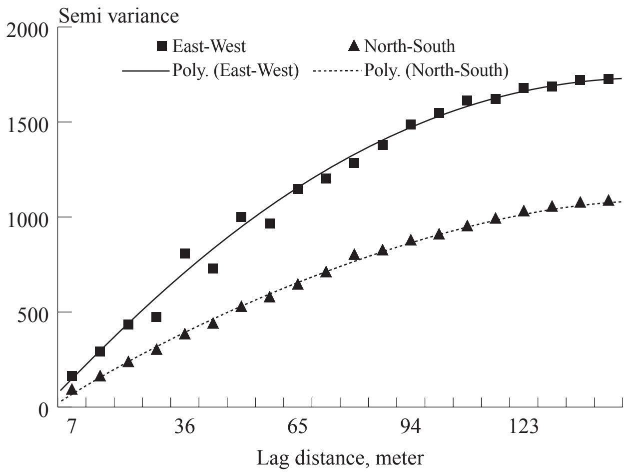


Fig. 9 Semi-variogram of P_2O_5 levels after treatment

Probability and Statistics. John Wiley & Sons, Inc. pp. 695
Deutch, C. V. and A. G. Journel, 1998. GSLIB: Geostatistical Software Library and User's Guide, 2nd Ed. New York: Oxford University Press.
El-Mowafy, A., 2000. Performance Analysis of the RTK Technique in an Urban Environment, the Australian Surveyor Journal, Volume (45), No. (1), June 2000
Fulton, J. P., S. A. Shearer, G. Chabr and S. F. Higgins, 2001. Performance assessment and model development of a variable-rate, spinner-disc fertilizer applicator. Trans. of ASAE, Vol. 44: 1071-1081.
Fulton, J. P., S. A. Shearer T. S. Stombaugh and S. F. Higgins, 2001. Pattern assessment of a spinner disc variable-rate fertilizer applicator. 2001 ASAE Annual International Meeting, Sacramento, California, USA, July30-August 1. Paper Number 01-1116
Genton, M. G. and D. J. Gorsich, 2002. Nonparametric variogram and covariogram estimation with Fourier-Bessel matrices. Computational Statistics & Data Analysis 41(2002) pp. 47-57. Elsevier Science B.V.
Herzfeld, U. C., 2002. Vario function of higher order-definition and application to characterization of snow surface roughness. Computers & Geosciences 28 (2002), Elsevier Science B.V. pp. 641-660..
Jin, J. and C. Jiang, 2002. Spatial variability of soil nutrients and site-specific nutient management in the P.R. China. Computers and Electronics in Agriculture. 36 (2002). Elsevier Science B.V pp.165-172.
Langley, R. 1998. "RTK GPS" GPS World, Vol. (9), No. (9), September 1998.
Lida, M., M. Umeda and P. A. Radite, 2001. Variable rate fertilizer applicator for paddy field. 2001 ASAE Annual International Meeting, Sacramento, California, July 30-August 1. Paper Number 01-1115.
Molin,J.P., L. A. A. Menegatti, L. L.Pereira, L. C. Cremonini and M. Evangelista, 2002. Testing a fertilizer spreader with VRT. Proceedings of the World Congress of Computers in Agriculture and Natural Resources, 13-15, March, Iguacu Falls, Brazil. pp. 232-237.
Perrier, E. R. and L. P. Wilding, 1986. An evaluation of computational methods for field uniformity studies. Advances in Agronomy 39, 265-312.
Pringle, M. J., A. B. McBratney, B. M. Whelan and J. A. Taylor, 2002. A preliminary approach to assessing the opportunity for site-specific crop management in a field, using yield monitor data. (Article under press) Agricultural Systems, Elsevier Science Ltd.
Royale, A. 1980. Geostatistics. McGraw-Hill, New York.
Sogaard, H. T. and P. Kierkegaard, 1994. Yield reduction from uneven fertilizer distribution. Trans. of ASAE. 37: 1749-1752.
Vogel, J. R., J. D. Garbrecht and G. O. Brown, 2001. Variability of selected soil properties in winter wheat and native grass watersheds. Applied Engineering ni Agriculture, Vol. 17(5), pp.:611-623.
U.S. Environmental Protection Agency. 1995. National water quality inventory, 1994. report to congress. EPA841-R-95-005. Office of Water. Washington, D.C. :USEPA.
Yang, C. , Everitt, J. H. and Bradford, J. M. 2001 . Comparisons of uniform and variable rate Nitrogen and Phosphorus fertilizer application for grain Sorghum. Trans. of ASAE. Vol. 44: 201-209.

■■

The Effect of Dilution Volume, Water Temperature and Pressing Time on Oil Yield from Thevetia Kernel during Extraction

by
A. F. Alonge
Department of Agricultural Engineering,
University of Ilorin,
Ilorin
NIGERIA
falonge6@yahoo.com

A. M. Olaniyan
Department of Agricultural Engineering,
University of Ilorin,
Ilorin
NIGERIA
amolan397@hotmail.com

Abstract

Experiments were performed to determine the effects of dilution volume, water temperature and pressing time on oil yield from the kernels of thevetia nuts using a laboratory press for applying pressure during the extraction process. Kernels of thevetia nuts were finely ground and mixed with 5, 10, 15, 20 and 25 ml of water at the temperatures of 20, 40, 60, 80 and 100 ºC and then expressed using the laboratory screw press, which exerted a pressure of 42.3 KPa over the meal for 5, 10, 15, 20, 25 and 30 min. The oil obtained from the expression was collected in a measuring cylinder through a funnel and weighed with accuracy of 0.01g. The data were analyzed by analysis of variance and Duncan' s Multiple Range Test using the COSTAT 3.0 package. Results of the analysis revealed that all factors and their interactions were significant on oil yield (at $P \leq 0.05$). Oil yield increased to a maximum value when the dilution volume was increased from 5 to 15 ml after which it decreased with further increases in dilution volume. The relationship between oil yield and water temperature did not follow a definite pattern. Oil yield increased progressively when the pressing time was increased from 5 to 30 minutes at all levels of dilution volume and water temperature.

Introduction

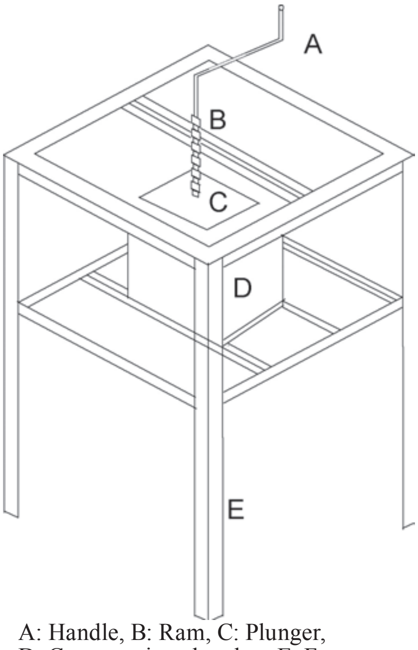
Thevetia (peruvianae) is commonly known as Allamanda after the French traveller - Adre Thevet. It belongs to the family of apocynacea. The fruit may be described as drupe, follicle or berries and is usually in pairs. The fruit contains oily cotyledon which, in turn, contains oil and fat. The seed is oblong in shape (tapered at both ends with the centre thicken). The seed mass ranged between 1.37 g and 6.00 g and the major diameter is about 22 mm long. According to Dutta (1974), the whole fruit consists of a membranous epicarp, a succulent mesocarp and a stony endocarp (shell) that encloses the embryo (kernel). Thevetia originated from Central America and is abundant in the tropics and sub-tropics. It is grown in Nigeria as an ornamental plant.

The oil extracted from the thevetia kernel can be used for both domestic and industrial purposes. Though, it is not presently being consumed by man, it is an alternative source of fat and is relatively less expensive. It is used in poultry diet, for dust control, in pelleting and also serves as a source of essential fatty acids. In its crystalline nature, the oil is very effective in the treatment of cardiac infections. Previous analysis by Jairo (1981) and Khan and Hanna (1983) revealed that the kernel contains about 64 % oil. For the oil to be extracted, the nuts must be cracked and the kernels recovered from the broken shells. They must undergo a series of mechanical and thermal processes and pretreatment such as size reduction, toasting and pressure application.

Fashina and Ajibola (1989) studied the mechanical expression of oil from conophor nut by investigating the effects of moisture content, heating temperature, heating time, applied pressure and duration of pressing on the yield of oil. They discovered that, generally the oil yield at any pressure was dependent on the moisture content of the sample after heating, heating temperature and heating time. High oil yields were obtained from samples with moisture content between 8 and 10 % after heating. The maximum oil yield of 39.6 %, corresponding to an extraction efficiency of 66 % was obtained when milled conophor nut conditioned to 11 % moisture was heated to 65 ºC for 28 min and expressed at a pressure of 25 MPa. Oil expressed under these conditions was of good quality with a free fatty acid value of 1.18 %.

Hamzat and Clarke (1993) performed oil expression tests in order to study the response of groundnut in terms of oil yield to process variables such as moisture content, present time, pressure, particle size and bed depth. Based on experimental and theoretical investigations, an equation was developed to relate the oil yield to the processing parameters studied. In developing the equation, the concept of quasi-equilibrium oil yield was adopted and the equation was found to fit the experimental data reasonably well.

Fig. 1 Isometric view of the laboratory press



A: Handle, B: Ram, C: Plunger, D: Compression chamber, E: Frame

One of the indigenous under-exploited vegetable oils that has high potential as industrial raw material is thevetia oil. The local method of extraction is not efficient and the output could not even meet the rural agro-industrial demand. Therefore, the objective of the study reported in this paper was to investigate the effects of dilution volume, water temperature and pressing time on the yield of oil extracted from milled thevetia nut kernel. Such information should enable the development of more efficient process and equipment for medium and large-scale thevetia oil extraction.

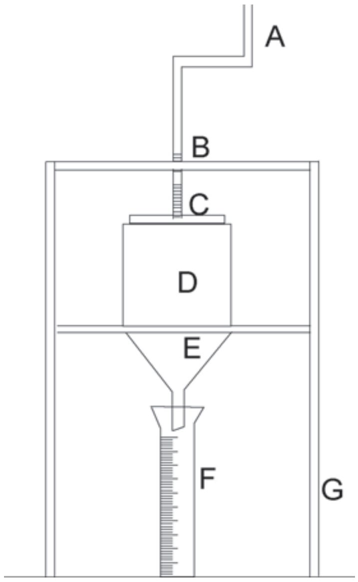
Materials and Methods

This study was carried out in the Processing and Storage Laboratory of the Department of Agricultural Engineering, University of Ilorin. The average room temperature was about 30 ºC throughout the period of experimentation.

The Laboratory Press

Extraction of thevetia oil from milled and heated simples of thevetia kernel was carried out using the laboratory press shown in **Figs. 1** and **2**. The press consisted of a turning bar, the threaded pressing ram, plunger, pressing chamber and the frame. The frame was made of a 35 mm angle iron. The height was 500 mm, the width 300 mm and the length 300 mm. The frame functioned as a rigid support for the pressing chamber and the ram, thereby maintaining tightness to aid the transmission of pressure uniformly over the period of time for which it was in use.

Fig. 2 Arrangements of the experimental apparatus



A: Handle, B: Ram, C: Plunger, D: Compression chamber, E: Funnel, F: Measuring cylinder, G: Frame

The pressing chamber was a square, hollow pipe in which the meal was placed for pressing. The base of the chamber was perforated to about 4 mm diameter to allow for the draining of the expressed oil. It was made of mild steel with dimensions of 100 mm by 100 mm by 150 mm. The turning bar was made of a piece of shaft 20 mm diameter and 180 mm long. It is used in rotating the pressing ram. The pressing ram was threaded in such a way as to produce a linear motion while rotation. The nut was welded to the frame to enhance rigidity.

The plunger was welded to the pressing ram, which was 82.5 mm by 82.3 mm and 4 mm thick. The plunger helped in transmitting pressure from the pressing ram evenly over the complete area of the pressing chamber and, for this reason, it was made to fit tightly into the pressing chamber with minimum clearance. The machine was designed in such a way that the plunger transmitted a pressure of 42.3 KPa to the pressing chamber during the extraction process.

Experimental Design and Procedure

A 5^2 x 6 factorial experiment in a split-plot design was used to evaluate the effects of five levels of dilution volume, five levels of water temperature and six levels of pressing time on the yield of oil extracted from milled thevetia kernel. The experimental design followed the method illustrated by Ott (1977), Miller and Freund (1987) and Miller et al (1990) for the design of multi-factor experiments.

Thevetia nuts were obtained from ornamental gardens in the University of Ilorin Staff Quarters. The nuts were parboiled to prevent the development of rancidity and toxic substances. The parboiled nuts were sun-dried, cracked and winnowed manually and then screened to recover clean kernels with a moisture content of about 6 %, dry basis (db). The kernels were milled in a hand plate mill and sieved into fine particles using a 2.00 mm standard sieve (ASAE, 1983). The milled product was divided into batches which were mixed with 5, 10, 15, 20 and 25 ml of water at the temperatures of 20, 40, 60, 80 and 100 ºC to form meal at different levels of dilution and different levels of temperature.

Samples of 100 g mass of meal were each transferred (at intervals) into the pressing chamber of the laboratory press after covering the base of the chamber with wire netting of 1 mm^2 and cheesecloth. Then, the turning bar of the press was rotated in the clockwise direction thereby pressing each meal sample for desired pressing time. The pressing times considered in the experiment were 5, 10, 15, 20 and 30 minutes. Oil was expressed through the perforated base of the pressing chamber into a funnel, which collects the oil in a measuring cylinder. The arrangement of the apparatus is shown in **Fig. 2**. The oil extracted from each sample was weighed directly by an OHAUS Electronic Balance (GT 480 Model) with accuracy of 0.01 g. Each experiment was replicated twice making a total of 300 test runs in the experiment.

Records and Analysis

The data obtained from the experiments were statistically analyzed by Analysis of Variance (ANOVA) and Duncan's Multiple Range Test (DMRT) using the COSTAT 3.0 package. This method was also illustrated by Ott (1977), Miller and Freund (1987) and Miller et al. (1990) for the analysis of multifactor experiments.

Results and Discussion

The data obtained from the experiments and the analysis of variance are presented in **Tables 1** and **2** respectively. From the analysis of variance table, it can be seen that all factors and their interactions were significant on oil yield at $P \leq 0.05$. The table also showed that pressing time was the most significant factor while dilution volume was the least. Of all the interactions, water temperature versus pressing time was the most significant while dilution volume versus pressing time was the least. The implication is that dilution volume, water temperature, pressing time and their combinations had effects on oil yield during oil extraction from milled thevetia kernel.

Effects of Dilution Volume on Oil Yield

The effect of dilution volume on oil yield during the extraction process is shown by the sensitivity analysis presented in **Table 3**. The table revealed that oil yield increased with increase in dilution volume from 5 to 15 ml and then decreased progressively with further increase in the dilution volume from 15 to 25 ml. This showed that the optimum dilution volume for maximum oil yield from thevetia oil extraction is 15 ml. This trend was true at all levels of temperature and

Table 1 Effects of dilution volume water temperature and pressing time on oil yield from thevetia kernel during extraction

Dilution volume (ml)	Water temper-ature (ºC)	Pressing time (min)					
		5	10	15	20	25	30
5	20	8.30	10.40	12.30	14.90	16.35	16.70
	40	10.50	12.75	14.85	15.25	16.45	17.10
	60	7.25	11.30	13.30	14.70	16.75	17.50
	80	5.40	9.40	11.65	13.30	16.00	19.65
	100	5.35	5.90	6.45	6.80	7.10	7.30
10	20	7.50	9.70	14.00	15.25	16.00	16.60
	40	19.85	21.10	22.90	22.90	23.65	23.90
	60	8.90	14.45	17.50	19.55	21.30	22.10
	80	8.10	11.70	14.80	17.20	17.20	18.95
	100	20.10	21.20	21.90	22.50	23.10	23.80
15	20	22.35	22.50	24.65	22.35	26.65	26.85
	40	21.40	23.40	23.75	24.50	24.50	25.75
	60	22.90	24.20	25.00	25.50	26.50	26.50
	80	6.50	11.10	13.70	14.80	15.50	16.20
	100	22.20	24.70	26.10	27.10	27.70	28.10
20	20	23.60	25.25	26.00	26.70	26.80	26.80
	40	21.45	25.95	26.75	27.40	27.45	27.50
	60	18.25	18.80	19.80	20.50	21.20	21.40
	80	16.20	18.30	20.40	21.20	23.30	24.70
	100	7.20	10.90	14.10	16.50	18.70	19.30
25	20	10.30	12.80	14.90	15.35	16.80	17.10
	40	18.25	18.80	19.80	20.75	21.20	21.30
	60	17.50	18.30	20.40	21.20	23.30	24.70
	80	7.50	9.70	14.00	15.40	16.00	16.60
	100	7.25	11.30	13.30	14.70	16.75	17.50

Note: Each value is the mean of two test samples pressing time as shown in **Table 1**.

According to Lindley (1991), oil-bearing materials have interparticulate forces, which are due to electrostatic bonding and the van der Waals forces, which tend to prevent segregation of aggregates and inhibit oil flow. Dilution and mixing enhance the displacement and segregation of aggregates such that there is structural rearrangement of the oil-bearing material all of which aid oil extraction. This may have been responsible for the initial increase in oil yield as observed in this study. However, according to Fashina and Ajibola (1990), at moisture levels above the optimum range, it is believed that swelling of the mucilage occurs and this in turn produces a cushioning effect on the oil seed. The swelled up mucilage may impede oil flow during expression while the cushioning effect on the oil seed reduces the rupturing of the particles and internal tissue during pressure application. This may have been responsible for the decrease in oil yield as the dilution volume was increased from 15 to 25 ml in this study.

Table 2 Analysis of variance of the effects of dilution volume, water temperature and pressing time on oil yield from thevetia kernel during extraction

Source of variation	Degree of freedom	Sum of squares	Mean square	F-value	Pr > F
Main effects:					
D	4	4,136.28	1,034.07	1,722.42*	0.00
T	4	1,598.69	399.67	665.72*	0.00
P	5	1,725.73	345.15	574.90*	0.00
Two-factor interaction					
D x T	16	2,939.80	183.74	306.04*	0.00
D x P	20	52.16	2.61	4.34	0.00
T x P	20	150.90	7.54	12.57	0.00
Three-factor interaction					
D x P x T	80	283.65	3.55	5.91*	0.00
Error	150	90.05	0.60		
Total	299	10,977.26			

*Significant at P ≤ 0.05; D, dilution volume; T, temperature; P, pressing time

Effect of Water Temperature on Oil Yield

Table 4 shows the sensitivity analysis of the effect of water temperature on oil yield from milled thevetia kernel. The table does not show any regular trend of relationship between water temperature and oil yield. The oil yield increased with an increase in water temperature from 20 to 40 ºC, then decreased when the temperature was further increased from 40 to 80 ºC and later increased again with an increase in the temperature from 80 to 100 ºC. The understanding is that hot water transmits heat to the milled product and aids oil extraction but the level to which this is done is not yet determined.

Generally, increase in oil yield with increase in water temperature as experienced in some cases in this study could be attributed to the fact explained by Olaoye (1994) that, cooking adjusts the moisture content to give the oilseed the proper plasticity for efficient oil extraction and also stops the action of enzymes. The effect of water temperature on thevetia oil extraction, as discovered in this study, may also have been due to the fact that cooking causes very small oil droplets to coalesce into drops large enough to flow from the oil bearing material and also increases the fluidity of the oil through increase in temperature, all of which aid oil extraction. However, as shown in **Table 1**, at higher pressing times (15-30 min) and at higher dilution volume (25 ml), oil yield increased to a maximum when the water temperature was increased from 20 to 60 ºC, after which there was a decrease in oil yield with further increases in temperature.

Effect of Pressing Time on Oil Yield

Table 5 shows the sensitivity analysis of the effect of pressing time on oil yield from thevetia oil extraction process. The table reveals that oil yield increased progressively when the pressing time was increased from 5 to 30 minutes. **Table 1** also shows that this trend is true at all levels of dilution volume and water temperature. This implies that a prolonged pressure application on milled thevetia kernel positively influenced thevetia oil

Table 3 Effect of dilution volume on oil yield*

Dilution volume (ml)	Oil yield (g)
5	12.18[e]
10	17.91[c]
15	22.50[a]
20	21.51[b]
25	16.42[d]

Table 4 Effect of water temperature on oil yield*

Water temperature (ºC)	Oil yield (g)
20	18.28[e]
40	21.47[a]
60	19.48[b]
80	14.82[e]
100	16.47[d]

Table 5 Effect of pressing time on oil yield*

Pressing time (min)	Oil yield (g)
5	14.06[f]
10	16.12[e]
15	18.00[d]
20	19.16[c]
25	20.28[b]
30	21.00[a]

Table 3, 4, 5*Means with the same letters are not significantly differsent at P ≤ 0.05 using Duncan's multiple range test extraction. This was to be expected because, generally, in the process of oil extraction by pressing, applied pressure increases the velocity of oil and thereby aids the oil flow through the interkernel voids. The pressure-time effect on thevetia oil extraction, discovered in this study, is in agreement with the findings of Fashina and Ajibola (1989), Fashina and Ajibola (1990), Sivala (1991) and Reddy and Bohle (1993). This study has shown that an increase in the pressing time at a certain applied pressure can aid oil recovery in most cases.

Conclusions

Oil yield from mechanical pressing of milled and hydro-thermal pretreated thevetia kernels was highly dependent on the processing factors: dilution volume, water temperature and pressing time. These factors should be taken into consideration when planning a wet extraction process for thevetia oil recovery.

The study revealed that high water temperatures might not be necessary for the extraction. This discovery, coupled with the fact that the nut is of high oil content, suggests that a mechanical extraction process might be more appropriate. It may even be assumed that an oil expeller would effectively squeeze out oil from the kernels by a mechanical process without any thermal pretreatments. Therefore, further study on the mechanical extraction process in relation to thevetia oil recovery merits high attention.

Acknowledgement

The authors acknowledge the assistance of Mr. O. D. Raphael during the experimentation.

REFERENCES

ASAE. 1993. Method of Determining and Expressing the Fineness of Feed Materials by Sieving. ASAE Standard: ASAE 8319. Agricultural Engineers Handbook. American Society of Agricultural Engineers: 325-327.

Dutta, A. C. 1974. Botany for Degree Students. Fourth Edition. Oxford University Press, U. K.

Fashina, O. O. and Ajibola, O. O. 1989. Mechanical Expression of Oil from Conophor Nut (Tetra-Carpidium Conophorum). Journal of Agricultural Engineering Research, 44:275-287.

Fashina, O. O. and Ajibola, O. O. 1990. Development of Equations for the Yield of Oil Expressed from Conophor Nut. Journal of Agricultural Engineering Research, 46:45-53.

Hamzat, K. O. and Clarke, A. O. 1993. Prediction of Oil Yield from Groundnut using the Concept of Quasi-equilibrium Oil Yield. Journal of Agricultural Engineering Research, 55(1):79-87.

Jairo, A. C. 1981. Phytochemical Study of Fixed Oil of Thevetia Peruviana Seed. American Journal of Medical Science: 189-193.

Khan, L. M. and Hanna, M. A. 1983. Expression of Oil from Oilseeds - A Review Journal of Agricultural Engineering Research, 28: 495-503.

Lindley, J. A. 1991. Mixing Processes for Agricultural and Food Materials 2: Highly Viscous Liquids and Cohesive Materials. Journal of Agricultural Engineering Research, 48 (4):229-247.

Miller, I. and Freund, J. E. 1987. Probability and Statistics for Engineers. Third Edition. Prentice-Hall of India Private Limited, New Delhi, India.

Miller, I.; Freund, J. E. and Johnson, R. A. 1990. Probability and Statistics for Engineers. Fourth Edition. Prentice - Hall of India Private Limited, New Delhi, India.

Olaoye, J. O. 1994. Oil Recovery Process from Shea Butter Seed through Modified Clarification, M. Eng. Thesis, University of Ilorin Library, Ilorin, Nigeria.

Ott, L. 1977. An Introduction to Statistical Methods and Data Analysis. Wadsworth Publishing Company, Belmont, California, USA.

Reddy, Y. S.; Bohle, N. G. 1993. Mechanical Expression of Oil from Mustard Seeds. Agricultural Mechanization in Asia, Africa and Latin American, 24(3):42- 46.

Sivala, K.; Bohle, N. G.; Mokherjee, R. K. 1991. Effect of Moisture on Rice Bran Oil Expression. Journal of Agricultural Engineering Research, 51:81-91.

■■

Postharvest Losses of Tomatoes in Transit

by

R. J. Bani
Professor
Department of Agricultural Engineering,
University of Ghana,
P. O. Box 68, Legon
GHANA

M. N. Josiah
Professor
Department of Agricultural Engineering,
University of Ghana,
P. O. Box 68, Legon
GHANA

E. Y. Kra
Professor
Department of Agricultural Engineering,
University of Ghana,
P. O. Box 68, Legon
GHANA

Abstract

Tomatoes are highly perishable and very susceptible to mechanical damage with poor handling and transportation. This study was conducted with the primary objective of establishing the current practices of handling and transportation of tomatoes from a main producing area, Bolgatanga, in the Upper East Region of Ghana, to a main marketing center, Accra, 815 kilometers away. The primary method was to interview the producers, tomato merchants and sellers in the market with the help of a prepared questionnaire. Observations were made on the journey from Bolgatanga to Accra. An assessment of losses along the route was found to be 20 %.

Introduction

Tomatoes (Lycopersicon esculentum) are of great nutritional value and are an important source of vitamins, and minerals. In spite of this importance, estimates of production losses in developing countries are high. In the continual fight against hunger and malnutrition, significant increases in food production have been achieved through the use of improved seeds, fertilizers and improved production practices. Of greater significance, however, is the amount of produce available to the consumer which can be achieved with reduction in losses. This will help to attain food security and poverty reduction. It is unfortunate that more than 30 years since the United Nations General Assembly resolution in 1975 to cut post harvest losses by 50 %, the world is nowhere near significantly reducing these losses, particularly in developing countries. Loss figures for tomatoes were considered to vary from 20-50 % (FAO, 1977) and very limited impact has been made in reducing these losses. It is necessary to insist on rigid quality standards where fruits or vegetables are being produced for high quality export markets. Quality standards used for tomatoes produced for export include:

- Appearance, size, color and shape.
- Condition or absence of defects including splitting and bruises.
- Ripeness.

Coursey and Proctor (1975) classified causes of loss into two categories; Social Causes and Technical Causes.

Social Causes of Loss

Under social causes are such considerations as the shortage of administrative and managerial skills and the shortage of capital. Lower levels of technology and of technological education are reflected in the lack of satisfactory handling and transportation techniques.

Technical Causes of Loss

Under technical considerations are the physical and physiological integrity of the produce. These must be preserved as losses occur as a result of assaults on this integrity. Mechanical injury to the fruit may occur at almost any stage in the postharvest journey of the produce. This includes the process of harvesting, unsuitable packing, transporting under unsuitable conditions and exposure in the market during sale. Delicate and sensitive produce such as tomatoes are often roughly handled and the damage inflicted greatly enhances further deterioration from physiological and phytopathological causes. A more detailed description of losses can be found in Tindall and Proctor (1980).

In Ghana, tomatoes are produced in large quantities in two areas; Akumadan in the Ashanti Region and Bolgatanga in the Upper East Region. The major marketing center for both of these producing areas is Accra, a distance of 300 km and 815 km away, respectively. The standardization of loss identification terms for tropical food commodities has been partially achieved by the National Academy of Sciences (1978) study. The primary areas of loss have identified as quantitative loss, qualitative loss and nutritional loss. The discussion in this paper is limited to quantitative loss, which includes losses due to damage incurred as a result of inadequate handling methods.

Postharvest Losses Due to Improper Handling during Transport

It is generally believed that fresh produce cannot be handled or harvested without inflicting injuries. Nevertheless, with careful groundwork and precaution, the damage can be appreciably minimized. Frequently, the injuries appear in the form of abrasive cuts and bruises. Bruises usually occur from impact and compression.

Determination of Losses

Determination of losses is difficult because they are very different in under various conditions and could vary from produce to produce over a period of time (Shukla and Royer 1984). Assessment is completely subjective while measurement is an objective determination of the samples selected. Estimation is the interpretation of measurement from which all losses can be extrapolated. Losses can be measured in monetary terms. They can also be measured and expressed by percentage of units or loss of weight.

Nature of injury	Cause
Abrasions and cuts	Rough surface of wooden crates. Uneven run of vehicles on rough surfaces creating instability in stucks
Bruising and crushing	Overfilled crates stacked on each other. Collapse of stacked crates.

Table 1 Nature and causes of injury during transit

Objective of the Study

• To establish postharvest handling and transportation practices of tomatoes from Bolgatanga in the Upper East Region of Ghana to Accra on the coast.

• To estimate the level of quantitative loss of tomatoes during the journey.

Methodology

A total of 25 tomato farmers from the Bolgatanga producing area, 5 tomato merchants, 2 drivers and 6 retailers in the market in Accra were interviewed. To observe at first hand the conditions of transportation, a journey was undertaken with a loaded truck of tomatoes from Bolgatanga to Accra.

Observation and Results of Loss Assessment

Harvesting

Harvesting was done by hand. The indices of maturity and time of harvests were subjective and were based on color, size and shape. Harvested produce was placed in plastic buckets and enamel coated pans until full, and then transferred into wooden crates (**Figs. 1** and **2**).

Transport Containers

The main container used for the transportation of tomatoes was a rectangular wooden crate measuring 620 mm long, 450 mm wide and 450 mm deep. The wall thickness ranged from 20 to 25 mm thick with 2 lateral openings of about 45 mm. These wooden crates were not padded.

Transportation

Transportation to the market center was by both open-ended trucks and closed trucks (**Fig. 3**). The vehicles had no refrigeration and, especially, in the case of closed trucks, this aggravated the condition of the tomatoes on arrival at the market.

Fig. 1 Enamel coated pans

Fig. 2 Wooden crates

Fig. 3 Open-ended trucks

Causes of Loss in Transit

Observations on the journey revealed the causes of loss as shown in **Table 1**.

Loss Assessment

Fifteen crates out of a total of 50 in a medium sized open-end truck were selected at random for the loss assessment. The number of tomatoes in each selected crate was counted at the beginning of the journey. At the end of the journey, that is, on arrival in Accra, the number of tomatoes in the selected crates were counted and sorted to determine the number lost as a result of spoilage. Tomatoes that were crushed or bruised were considered spoiled. The results are shown in **Table 2**.

Conclusion

Tomatoes provide a rich source of vitamins and other minerals needed for growth and development. However, it is a highly perishable crop with very high levels of losses reported 20-50 % (FAO). Proper handling of the produce from the farm gate to the market will ensure that the level of losses will be reduced to a minimum. Good quality packing crates with smooth or padded surfaces and good transport vehicles traveling on good roads will reduce losses that the study has shown to be 20 %.

Number of tomatoes in container	Number of tomatoes crushed/ bruised	Percentage loss
1,200	257	21
1,205	259	21
1,200	270	23
1,190	262	22
1,204	197	16
1,210	216	18
1,222	265	22
1,240	230	19
1,215	246	20
1,254	276	22
total: 12,140	total: 2,478	av.: 20.4

Table 2 Numbers and percentage losses

REFERENCES

Coursey, D. G. and F. J. Proctor, 1978 Towards the qualification of Post harvest loss in horticultural Produce. Acta Horticulture 49 15-56.

FAO, 1977 Analysis of an FAO Survey of Post harvest Crop Losses in Developing Countries. AGPP: Misc/27 Rome.

National Academy of Sciences, 1978 Post harvest Food Losses in Developing Countries. National Academy of Sciences Washington D.C.

Shukla, R. J. and J. C. Royer 1984 Proceedings of the 20th Annual Meeting of Caribbean Food Crops Society. ST Croix, U.S. Virgin Islands.

Tindall, H. D. and F. J. Proctor 1980 Loss Prevention of Horticultural Crops in the Tropics. Prog. Fd. Nutr. Sci. Vol. 4, No. 3-4 pp. 25-39, Pergamon Press.

■■

The Present State of Farm Machinery Industry

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

Outlook of Agriculture

Trend of Agriculture

In 2002 agricultural total products was ¥5,225 billion, accounting for 1.0 % of GNP. The agricultural products imports was ¥4,299 billion in 2001, ¥4,301 billion in 2002, ¥4,368 billion in 2003. The agricultural products exports was 302 billion in 2001, ¥206 billion in 2002, ¥196 billion in 2003.

Japan depends on imports for large part of domestic consumption of feed cereals, soybean, wheat. Food self-sufficiency rate was 40 % by calorie base in 2003, 27 % for cereals, almost the same as preceding year.

Population mainly engaged in farming has been decreasing yet, 2.59 million in 2003, 4.1 % of total working population. The number of Farm houses decreased to 2.98 million in 2003. 74 % of them are commercial farms selling their products in market. Total arable land in Japan was 4.74 million ha in 2003.

Japanese have been getting to enjoy more a variety of food since 1970's. The production of rice, oranges, milk, eggs has exceeded domestic consumption. Under such circumstances, GATT New Round Agreement gave great impact to Japanese agriculture. In order to get world competitive power, saving of production cost became the urgent issue. Other big issues in Japanese agriculture are, to have enough people engaged in farm work to maintain stable agriculture, production of high quality and safe products to meet the needs of consumers, and preservation of natural environment in rural areas.

In July 1999, Japanese government enacted the New Agricultural Stable Law, which aims to assure constant food supply by raising domestic production, to encourage multi-functions of agriculture, to have sustainable development of agriculture and to promote the development of rural areas. The law makes it a target that 50 % of national food consumption is covered by domestic production, at least to raise self-supply rate up to 45 % by 2010. In 2000 Japanese government enacted guidelines for dietary patterns to improve national dietary, the Food Recycle Law to decrease food waste, the revised Japanese Agricultural Standards (JAS) Law to improve food safety. BSE incident in 2001, food display forgery incident and usage of nonregistered agricultural chemicals in 2002 made the government to take measures for food safety.

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. Now rice production is almost mechanized from planting to harvesting. In 2002, average working hours on 10a paddy field reduced to 31.0 hours from 117.8 hours in 1970.

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

From 1993 to 1997, government carried out Urgent Development Project to intensify the development of high performance farm machines to raise farm productivity and reduce farm work burden. From 1998 to 2002, government carried out 2nd Urgent Development Project to develop new machines for 21st century which are useful in environmentally kind agriculture and useful for labor saving in mountains area. The government has carried out "Next Generation Agricultural Machinery Urgent Development Project" since 2003. Under these projects, 43 types of high performance machines were developed. They are, a large all-purpose combine, a full automatic vegetable transplanters, riding-type vegetable cultivator, and a Japanese leek harvesting machine.

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

Following are the numbers of farm machines in possession of commercial farm household of Feb. 1, 2000: riding tractor reached 2,028,000 units; walking tractor 1,048,000; rice transplanter 1,433,000; head feed combine 1,042,000.

Shipments of major farm machinery in the domestic market in 2004 are as follows: riding tractor 60,964 units (under 20 PS were 12,951; 20 to 30 PS 27,827; 30 to 50 PS 12,303; over 50 PS 7,183); walking tractor 142,316; rice transplanter 45,065; combine head feed types 30,433, standard types were 703; grain dryer 30,868; huller 22,880. The shipment of safety cabins and safety frames attached to tractors rose sharply to 60,625 units.

Table 1 Major farm machinery on farm (Unit: thousand)

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Binder	Combine	Rice dryer
1970	3,269	183	32	2,178	261	45	1,227
1975	3,426	501	740	2,607	1,327	344	1,497
1980	2,752	1,471	1,746	2,139	1,619	884	1,524
1985	2,579	1,854	1,993	2,151	1,518	1,109	1,473
1990	2,185	2,142	1,983	1,871	1,298	1,215	1,282
1995	1,344	2,123	1,650	1,714	836	1,120	1,052
2000	1,048	2,028	1,433	1,269	583	1,042	861

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheris" by the Ministry of Agriculture, Forestry and Fisheries.

Table 2 Shipment of major farm machinery (Unit: number)

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Binder	Combine	Rice dryer
1997	174,004	87,416	64,859	175,164	16,770	53,095	51,655
1998	173,397	71,840	52,337	157,335	11,757	41,282	38,127
1999	180,511	72,533	59,529	164,656	12,010	40,822	38,720
2000	166,996	72,554	55,386	162,030	10,648	40,888	33,159
2001	145,557	65,933	47,285	154,516	8,019	35,685	29,585
2002	142,774	64,781	48,054	150,035	6,991	34,397	28,893
2003	157,470	66,287	47,303	149,949	5,680	34,137	27,609
2004	142,316	60,964	45,065	154,049	5,421	31,136	30,435

Source: "Survey of Shipment of Agricultural Machinery" by the Ministry of Agriculture, Forestry and Fisheries.

Plans for Farm Mechanization

2005 government budget for farm mechanization was used for;

• Development of high-performance machine and technology; “Next Generation Agricultural Machinery Urgent Development Project” in collaboration with manufacturers, universities and institutions promoted the development and popularization of the machines needed in local agriculture and sustainable agriculture.

• Saving of agricultural machinery cost: education for cost saving, raising farm work contractors.

*Prevention of farm accident.

Government Budget for Agriculture, Forestry and Fisheries

2005 government budget for agriculture, forestry and fisheries was 2,967.2 billion yen in total. Major subject items are;

• Food supply under safety and risk control.

• Acceleration of structural reform in agriculture.

• Preservation of agricultural environment and resource.

• Promotion of agricultural products export.

• Technology development to increase international competitive power.

• Practical use of biomass.

• Preservation of diversified and healthy forest.

Movement of Farm Machinery Industry

In recent years Japanese agriculture is gradually moving toward bipolarization, large scale farming and small scale farming. Agricultural machinery manufacturers have put the machines to meet such market situation. In local agricultural machinery shows, the number of medium size machines in exhibition is decreasing while more small and large size machines are exhibited.

The contract farming is further going on particularly in rice cropping. Small and medium scale part-time farmers are more apt to put the farm work to contractors, rather than buying expensive machines only for weekend farming. A part or all of their farm work is undertaken by large scale farmers or agricultural production enterprises.

Ministry of Agriculture, Forestry and Fisheries regards authorized farmers and agricultural production enterprises as key force to undertake future agriculture, and give full support to them through various measures. That will further accelerate the movement toward bipolarizaton in agriculture. For large scale

Table 4 Farm equipment distributor and sales value (Unit: million yen)

Year	No. of retailers (1)	Employes	Annual sales value (2)	Inventory	Square meters of shop m^2	Annual sales value (2)/(1)
1985.6	9,142	43,921	946,507	144,837	985,453	103.5
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5
1991.6	9,480	45,705	1,158,924	170,104	984,700	122.2
1994.6	8,838	43,112	1,128,087	166,298	978,788	127.6
1997.6	8,820	45,090	1,265,902	170,350	901,851	143.5
2002.6	8,123	40,441	979,066	145,725	982,529	120.5

Source: Ministry of Economy, Trade and Industry.

farmers and agricultural production enterprises which undertake a large amount of farm work, the most serious problem is unexpected trouble with machines.

While simple troubles can be fixed by users, many troubles have to be repaired by agricultural machinery dealers. It is absolutely necessary for dealers to handle them quickly as soon as receiving a call from users. Speedy and flexible response of dealers helps establishing strong connection between dealers and users. Maintenance and repair service operations by dealers will be more important in the future.

On the other hand there is a continued demand for small machines, used by small farmers who intend to maintain their farm land with no thought of profit. The number of the people who start farming after retirement is also increasing.

To cope with further developing diversity of the market, agricultural machinery manufacturers need to have clear understanding of end-users' requirements through daily contact and feed them back to machinery design and development.

Trend of Farm Machinery Production

Farm machinery production in 2005 amounted to ¥504.3 billion (5.5 % increase over the preceding year) by JFMMA (Japan Farm Machinery Manufacture's Association) statistics. The production for domestic market was 340.9 billion yen, 103.2 % of the preceding year. The production for export was 163.4 billion yen, 110.8 % of the preceding year.

Production of the major farm machinery is as follows: Wheel type riding tractor 198,913 units increased by 4.7 % over the preceding year. By H.P., those under 20 PS amounted to 27,001 units, 20 to 30 PS 80,331 units, 30 to 50 PS 63,498 units, over 50 PS 28,083 units. About 70 % of the total production is for export.

The production of walking tractor amounted to 199,864 units, which showed an increase of 3.0 % over the preceding year. The production of over 5 PS walking tractor is on the decrease.

The production of combine, which is next to the riding tractor in production amount, is 37,340 units (a increase of 19.5 % under the preceding year). The most popular type is with harvesting width of one meter head feed.

Following are the production of

Table 3 Yearly production of farm machinery (Unit: number, million yen)

Year	Total		Walking type tractor		Riding type tractor		Rice transplanter		Power sprayer		Blower sprayer	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1998	-	491,973	212,551	29,669	144,774	194,954	53,122	46,218	156,890	7,256	7,973	9,204
1999	-	539,960	253,817	36,365	156,452	220,047	58,137	43,146	153,118	7,416	7,194	9,282
2000	-	520,956	243,995	31,647	163,536	204,339	56,784	44,887	162,527	7,763	6,000	9,896
2001	-	453,946	191,941	25,372	135,353	170,063	50,918	41,887	139,360	6,036	6,465	9,854
2002	-	456,024	174,683	22,172	149,202	184,843	47,911	40,696	191,940	7,953	4,907	7,691
2003	-	450,156	164,536	21,431	174,514	202,519	51,457	44,643	173,047	12,774	4,716	6,715
2004	-	478,039	194,018	24,444	190,116	234,100	47,522	42,606	184,221	14,881	3,984	6,421
2005	-	504,336	199,864	25,810	199,581	248,287	49,631	45,121	162,511	11,715	3,611	6,145

Year	Grain reaper		Brush cutter		Grain combine		Rice husker		Dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1998	8,631	2,336	1,012,372	22,236	40,196	103,435	28,113	10,705	32,968	26,543	39,729	3,588
1999	11,816	3,436	1,084,889	24,172	42,173	112,145	37,579	14,491	36,920	29,976	36,342	2,464
2000	11,291	3,104	1,011,889	23,132	41,137	100,671	26,089	9,784	35,780	29,227	39,235	7,667
2001	8,172	2,274	963,965	20,200	36,158	91,210	23,973	9,209	31,567	26,007	36,427	6,972
2002	6,779	1,853	952,898	19,715	35,658	94,608	21,630	8,347	32,160	25,697	25,006	3,842
2003	5,664	1,521	836,409	19,333	36,899	90,811	26,174	9,827	27,419	21,730	27,975	1,825
2004	5,116	1,451	901,688	20,195	31,251	85,375	23,305	8,288	28,761	22,229	29,106	1,857
2005	5,940	1,686	890,978	20,391	37,340	99,996	22,373	8,304	27,111	22,143	25,846	1,518

Source: 1996-2002; "Survey of Status of Machinery, Production" by the Ministry of Economy, Trade and Industry, 2003-2005; JFMMA (Japan Farm Manufacture's Association statistics.

other types of farm machinery; rice transplanter amounted to 49,631 units (a increase of 4.4 % under the preceding year), grain dryer 27,111 units (an decrease of 5.7 %), huller 22,373 units (a decrease of 4.0 %), bush cleaner 890,978 units (an decrease of 1.2 %), power pest-controller 223,147 units (an decrease of 10.9 %), binder (walking type cutter for rice and wheat) 5,940 units (a increase of 16.1 %), thresher 2,629 units (a increase of 3.4 %), foder cutter 33,949 units (a increase of 15.8 %), rice pearling machine 25,846 units (an decrease of 11.2 %), rice sorter 20,620 units (a increase of 4.3 %),

Trend of Farm Machinery Market

In Japan distribution systems for farm machinery is roughly divided into two major channels; the dealers concerned and Agricultural Cooperatives Association. As of June 2002, the retail shops were recorded to about 8,100, the employees amounted to 40,000 persons, and the annual sales amounted to ¥979 billion.

According to the governmental survey by Ministry of Agriculture, Forestry and Fisheries, the total sales of farm machinery by Agricultural Cooperative Association reached ¥272.4 billion in 2003 (¥284.3 billion in 2002). The number of Agricultural Cooperative was 947 in 2003. Average sales amount per cooperative increased to ¥290 million.

About half of private dealers are small firms which less than 5 employees. In a long time view, with less demand for agricultural machines expected in future, improvement of management structure will be needed.

Export and Import of Farm Machinery

Export

In 2005 the export of farm machinery amounted to ¥225.1 billion, which showed an increase of 12.3 % over the preceding year.

By the export destination, ¥134.0 billion for North America (an increase of 6.6 %), ¥40.6 billion for Europe (an increase of 16.8 %), ¥39.0 billion for Asia (an increase of 30.4 %). For North America, ¥126.7 billion was for USA, tractor 116,092 units, ¥112.6 billion, which was a major part. Tractors for Asia is 31,742 units, but maker's shipment is only about 3,200 units, others are considered to be secondhand machines.

By the types of machines, tractor (consists main part of export); 190,764 units were exported in 2005, it amounted to ¥153.7 billion. Seeing by horse power, those under 30 PS amounted to 105,700 units, those from 30 to 50 PS 63,177 units, those over 50 PS 21,887 units.

Major farm machinery, next to tractor, is bush cleaner. The total exports were 1,001,115 units, ¥21.8 billion. The exports of other farm machinery are as follows; walking tractor 43,931 units; power sprayer 36,066 units; lawn mower 55,587 units; grass mower 52,794 units; chain saw 327,452 unit, etc.

Import

In 2005 the imports of farm machinery amounted to ¥44.7 billion, which means an increase of 9.9 % over the preceding year.

Major imported farm machines:

Table 5 Export of farm equipment 2005 (Unit: FOB million yen)

Year	Unit	Value	Ratio	Major destinations
1998		143,843		
1999		149,066		
2000		139,049		
2001		126,173		
2002		148,581		
2003		160,734		
2004		200,533		
2005		225,131	100.0	USA, Korea, France
Seeder, planter	6,322	5,721	2.5	Korea
Power tiller	43,931	3,178	1.4	Belgium, USA, Spain
Wheel tractor	190,764	153,662	68.3	USA
Power sprayer	36,066	1,203	0.5	USA, Korea, Taiwan
Lawn mower	55,587	6,618	2.9	France, Germany
Brush cutter	1,001,115	21,824	9.7	USA, France, Italy
Mower	52,794	1,328	0.6	USA, China
Combine	2,589	5,119	2.3	Korea, Taiwan
Grain separator	727	3,200	1.4	China, India, Thai
Chain sow	327,452	6,950	3.1	USA, Italy, France
Others	-	16,328	7.3	

Table 6 Import of farm equipment 2005 (Unit: CIF million yen)

Year	Unit	Value	Ratio	Major destinations
1998		27,513		
1999		23,308		
2000		25,825		
2001		32,603		
2002		33,988		
2003		36,828		
2004		40,719		
2005		44,742	100.0	Germany, China, France
Wheel tractor	3,059	14,390	32.2	France, Germany, UK
Pest control machine	-	2,124	4.7	China
Lawn mower	183,085	2,953	6.6	USA
Mower	4,893	2,286	5.1	France, Germany, Italy
Hay making machine	982	760	1.7	France, Germany, NL
Bayler	691	1,567	3.5	Germany, Italy, France
Combine	125	1,775	4.0	Germany, Belgium
Chain sow	68,193	1,089	2.4	Germany, USA, Sweden
Others	-	17,798	39.8	

Source: Ministry of Finance. Totaled by Japan Farm Machinery Manufactures' Assn.

tractor 3,059 units (those more than 70 PS were 2,518 units of all the tractor); chain saw 68,193 units, lawn mower 183,085 units, mower 101,957 units, fertilizer distributor 2,510 units. Tractors 740 units were imported from France, and 579 units from German, 506 from Italy, 504 from UK.

Trend of Research and Experiment

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

The government issued "Basic Research Plan for Agriculture, Forestry and Fisheries" in March, 2005 to set the objectives of the development in the future ten years. In the field of next generation farm mechanization technology development.

It is encouraged to develop "high performance production control system with IT technology", "labor and energy saving, safe production system utilizing automation technology" and etc.

Research results by BRAIN (Bio-oriented Technology Research Advancement Institution) in 2004 were;

New seeding technology for rice and soybean, High quality manure production technology, Unmanned operation system for agricultural machinery, Management support system and Safe operation support system utilizing IT technology. ■■

ABSTRACTS

The ABSTRACTS 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.

326

Adequacy of Testing Facilities for Farm Machinery in Indian Punjab: **Kamal Vatta**, Research Officer, Agro Economic Research Centre, Department of Economics and Sociology, Punjab Agricultural University, Ludhiana-141004, India, **Sanjay Kumar**, same

The present paper intends to assess the existing testing infrastructure, its relevance and adequacy in the State. There is a Farm Machinery Testing Unit, located at Punjab Agricultural University, Ludhiana, which conducts the tests for a variety of farm machines and equipment. At present the testing infrastructure is not even sufficient to take care of the present level of farm machines and equipments. There is need to increase the personnel as well as physical resources in the testing centers. The manufacturers, although aware of the contribution of machinery testing to quality improvement, shirk from getting these tested because it adds to the cost of production and shrinking profit margins due to large number of small manufacturers entering the production without any check. More efforts should be initiated for encouraging the testing of those farm machines and equipments, whose cost of production is above some limit (say around Rs. 20,000) and whose volume of demand is very high. There is a need for a separate testing centre in Punjab as the State is not only a major manufacturer of agricultural machinery and equipments in the country but also has the major demand for these. It is also important to keep the cost of testing the agricultural equipment and machinery down from the manufacturers' point of view. The Central and the State governments should meet these costs on sharing basis and keep these expenditures in the Blue Box subsidies as allowed in WTO.

332

Effect of Seed Storage Conditions on Emergence of Healthy Seedling of Soyabean (cv. Lee): **G.H. Jamro**, Faculty of Crop Production, Sindh Agriculture University, Tandojam 70060, Pakistan, **L.A. Jamali**, Faculty of Agricultural Engineering, same, **M. Hatam**, Department of Agronomy, Peshawar Agriculture University, Peshawar, Pakistan, **S.K. Agha**, Faculty of Crop Production, Sindh Agriculture University, Tandojam 70060, Pakistan

Experiments were conducted at Agriculture University Peshawar, Pakistan to study the effect of seed storage condition on the emergence and healthy seedling of soyabean (cv. Lee) under field conditions. The treatments were cloth bags, plastic bags, gunny bags, pitchers, tin cans, pods and refrigerator. Each treatment was replicated three times in randomized complete block design. Data revealed that field emergence was significantly different for sampling dates as well as storage containers. Seed emergence was greater in early sowing crop and seed stored in pods and refrigerator respectively. Further data demonstrated that storage containers were significantly affected the percentage of healthy seedlings. The seed stored in pods and refrigerators has 51.6 % and 52.8 % healthy seedlings respectively.

333

Effect of "Keeping Temperature" on Organoleptic Quality of Curds: **Krishna Kumar**, Professor & Head and Associate Professor respectively, Department of Agro Processing and Rural Industry, College of Agricultural Engineering and Technology, N.D. University of Agriculture & Technology, Kumarganj-224 229, Faizabad U.P. India, **Mahendra Rai**, same

Keeping temperature plays an important role in making quality curds. Temperatures above optimum, adversely affect the organoleptic parameters of the curds. This experiment was conducted to see the behaviour of organoleptic parameters of soy-milk curd and buffalo milk curd at different keeping temperatures. Above optimum temperature of 25 ºC, all the quality parameters of the different curds indicated gradual decrease in values till 35 ºC and quality loss increased faster then after except acidity. Acidity scores decreased from optimum temperature to 35 ºC and it again increased till 45 ºC.

344

Performance of an Evaporative Cooler: **M.N. Josiah**, Agric. Engineering Department, Faculty of Agriculture, University of Ghana, Legon. Ghana, **R.J. Bani**, same, **E.Y. Kra**, same

Green plantains were stored in an evaporative cooler built of wooden frame covered with cotton cloth as the absorbing surface. Temperatures and relative humidities inside and outside the cooler were measured by a thermohydrograph. An Effigi penetrometer was used to determine the firmness of the plantains after 8, 10, and 14 days. The results indicated that the evaporative cooler with an efficiency of 74 percent, and maintaining a steady temperature of 27.7 ºC and steady relative humidity of 97 percent delayed the ripening process of green plantains for up to 12 days, with only 1.10 percent weight loss.

345

Comparative Evaluation of Manual and Mechanical Raw Mango Slicing: **Syed Zameer Hussain**, Division of Agr. Engg. U.A.S. Banglore and Division of Food Engg. IIHR, Hessaraghatta Banglore, India

The Raw mango slicer very useful to raw mango processing industries consists of four shafts rotating on bearings and powered with 3 HP A.C. motors connected separately to the shaft by a chain and sprocket transmission system. The shaft with circular blades rotate at 750 rpm. Two pair of shaft rotate perpendicular to each other. One set of shafts has one blade on each shaft. The other set has one, two and three blades on each shaft which cut the mangoes into 4, 6 and 8 slices depending on its size. The Raw mango slicer was evaluated for different varieties namely Neelum, Alphonso, Langra, Raspuri, Totapuri and Chinnarasam and results were compared with manual slicing. The analysis of the data reveals that the slicer was significantly over manual slicing, when the slicing capacity and labour requirement were taken as the parameters. Regarding slices with endocarp the difference between manual and mechanical slicing was found to be non significant for Alphonso, Raspuri, Totapuri and Chinnarasam varieties. However, it was found to be significant at P (0.05) for Neelum and Langra varieties. Regarding slices with mechanical damage, the difference between manual and mechanical slicing was found to be non-significant for all the varieties.

350

Applications of Solar Energy in Agricultural Products Drying: **Jamal Nourain**, Ph. D. Candidate, College of Biosystems Engineering & Food Science, Zhejiang University, Hangzhou, Zhejiang 310029, P.R. China, **Ying Yibin**, Executive Dean and Professor, same

Solar drying is one of the methods for preserving food in remote areas. Many approaches have been proposed and developed for the solar drying of crops and other produce. This review paper described the techniques of solar drying and then provided examples, which illustrated how this technology could utilize locally available materials in the construction of the drying units. The solar drying systems generally classified into two types, direct dryers in which solar radiation is absorbed directly by the produce and indirect dryers in which the solar radiation is used to heat air which then flows through the volume containing the produce. There are four common drying techniques that are utilized for drying agricultural products, such as open air drying, firewood/fuel drying, electrical drying and PV1 powered or simple drying.

479

Study On Crop Precision Irrigation System Based On The Virtual Instrument Technique: **Bao Yidan**, Associate Professor, Department of Biosystems Engineering, Zhejiang University, Hangzhou 310029, Zhejiang Province, P.R. China, **He Yong**, Professor and Dean, College of Biosystems Engineering and Food Science, same, **Wu Yanping**, Ms.c. Student, same

The research aims are exploring the special crop's water demand, the affective of soil moisture and environment temperature in crop's different growth periods, Creating an automatically controlment irrigation system to implement the crop precision irrigation. This irrigation system was determined using the following procedures: (1) Nation Instruments' graphical programming LabVIEW, DAQ broad (PCI-6024E), a series of temperature, soil moisture and dielectric properties of plant sensors, signal conditioning circuit were required to detect the information, and GPS (AG132) was located the sample points in real time. (2) The signals through Nation instruments' DAQ-6024E broad and GPS position information from Map 330 receiver by RS-232 serial interface were all combined to the irrigation system with other crops knowledge in Access database to analyze crops water requirement situations. (3) According to the information analysis, fuzzy control aided by NI control toolkit was put out irrigational signals to deal with irrigation execution units for watering. Many basic information operations functions, such as data display, store and analysis were provided. Moreover, it has accomplished a GIS function, making watering spot and its corresponding information visible to operators in GIS map, which was convenient for operators to master both current and basic irrigation information. The whole accomplished system has shown its great intelligent functions on signals acquisition, analysis, control compared with traditional irrigation ones.

510

Energy Requirement of Different Weed Management Practices for Wheat in Indo-Gangetic Plain Zone for India: **V.P. Chaudhary**, Scientist, Project Directorate for Cropping Systems Research, Modipuram, Meerut-250110 (U.P.), India, **D.K. Pandey**, Tech. Officer, same, **B. Gangwar**, Principal Scientist, same, **S.K. Sharma**, Principal Scientist, same

The analysis of the energy requirements for the wheat (Triticum aestivum L.) was carried out at the research farm of Project Directorate for Cropping System research, Modipuram, Meerut during the year of 2000-01 to 2003-04. The different weed management practices such as hand weeding twice, herbicides + one hand weeding, criss-cross sowing + one hand weeding, criss-cross sowing + herbicides + one hand weeding, unweeded check were subjected to wheat crop to assess the energy use, one put energy obtained and net return of energy. Result revealed that the total input energy utilization in wheat varied from 19,589.0 MJ/ha to 20,472.1 MJ/ha for treatments unweeded check and criss-cross + herbicides + hand weeding, respectively. The energy use by inorganic fertilizers represented the major part of total energy use accounting about 50 percent followed by machinery used about 20 percent in all treatments, whereas, irrigation consumed about 17 percent energy use of total input energy. Total amount of energy use in weed management was varied from 1.93 to 4.22 percent of the total input energy. The hand weeding twice was found to be more energy consuming than other treatments. This was followed by herbicides + hand weeding once as well as criss-cross sowing + herbicides + hand weeding once. The energy utilization for weed management was found from 11.6 to 21.9 percent higher in traditional seedbed as compared with stale seedbed.

The criss-cross sowing + herbicides + hand weeding once gave from 71 to 76, from 18 to 19, from 14 to 15 and from 1 to 3 percent higher output energy as compared with unweeded, criss-cross sowing + hand weeding once, hand weeding twice and herbicides + hand weeding once, respectively. The net return energy, among five treatment, was found to be significantly high in treatment criss-cross sowing + herbicides + hand weeding one (i.e. 71,583.9 MJ/ha) was the statistically at par with herbicides + hand weeding one (i.e. 701,128.2 MJ/ha) which were significantly higher than other treatments. This was followed by hand weeding twice (i.e. 58,168.6 MJ/ha) which was non-significant higher than criss-cross sowing + hand weeding once (i.e. 54,473.9 MJ ha). The net return energy in criss-cross sowing + herbicides + hand weeding once was found from 89 to 96 percent higher than unweeding, from 23 to 25 percent higher than criss-cross sowing + hand weeding once, from 18 to 20 percent higher than hand weeding twice and 3 percent higher than herbicides + hand weeding once.

516

The Philrice-B&S Minicombine Harvester (Tests and Improvements in the Philippines and Vietnam): **Eulito U. Bautista**, Scientist III, Phil. Rice Research Institute, Munoz 3119, Nueva Ecija, Philippines, **Phan Hieu Hien**, Director, Center for Agricultural Energy and Machinery, Nong-Lam University, HoChi Minh City, Vietnam, **Alfred Schmidley**, Director, Business Development-Asia, Briggs & Stratton International East Asia Corporation, Shanghai, China

Rice harvesting and related operations remain as laborious and time consuming tasks in most Asian countries mainly because they are still manually done. Although rice threshers have been introduced to reduce the time and labor on the system, harvesting and gathering of harvested stalks remain as drudging and laborious tasks. Small walking-type reapers have also been introduced with limited success since the reaper still relies on manual labor for gathering before feeding the stalks into a thresher. Some Asian countries have benefited on reapers but many countries do not see this as a permanent solution.

The combine harvester presents a highly feasible and efficient alternative to manual system or reaper harvesting as it allows quick turnaround time between the first and second crop, more efficient field handling of paddy output (less losses, time, and labor), as well as cheaper harvesting cost and better paddy quality (no exposure to field elements over time). In Malaysia, reconditioned combines have been intensively used for many years now while Thailand manufacturers innovated in 1990s a large combine based on surplus chassis of track-type construction vehicles. China has a mixture of different combines patterned from European and Japanese designs although a few models are simple innovations by small companies.

In the Philippines, as in many Asian countries, the only option is to buy expensive imported combine. There were many attempts in the past to introduce imported combine harvesters in the Philippines. However, the imported models were mostly confined to field trials because of their size vis-á-vis small paddy sizes, heavy weight that causes bogging down in wet soft fields during the wet season, sophisticated mechanisms that are difficult to repair or replace locally, and high investment and maintenance costs. In Vietnam, attempts by government agencies and field mechanics to introduce and develop smaller models were similarly saddled by problems of heavy weight (>1 ton machine weight), reliability (local prototypes operated only for 1 h before breakdown), and difficulty of the machine to handle lodged crops.

526

Studies on Hardened Hoof Shoes for Bullocks in Udaipur and Jaipur Regions of Rajasthan: **G.S.Tiwari**, Department of Farm Machinery and Power Engineering, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur, Rajasthan, India, **Rajeev Garg**, same, **H.Shrimali**, same, **R.N.Verma**, same

A survey was conducted in the Udaipur and Jaipur regions of Rajasthan to collect the information regarding hoof shoes. According to the design of locally manufactured hoof shoes, shoes of different sizes and weight were got fabricated and hardened by different hardening process. Hoof shoes hardened with powder coating and weld deposition were shoed in the bullocks used for transportation purpose. The life of hardened hoof shoes was compared with the locally available traditional hoof shoes. The powder coated hoof shoes lasted longer as compared to weld deposited and traditional hoof shoes.

531

Evaluation and Standardization of Paddy Threshing Techniques: **Syed Zameer Hussain**, Department of Agr. Engg. KITE Polytechnic Kashmir, India, **Junaid Khan**, Division of Agr. Engg., Sher-e-Kashmir University of Agricultural Sciences and Technology-Kashmir, India

In some parts of India and particularly in Jammu and Kashmir State the paddy is threshed in a traditional way of beating bundles of paddy against drum or wooden logs, which is very tedious, laborious and time consuming. Thus, the study which aim to document and to study the various methods of threshing namely power operated paddy thresher (T_1), handle operated paddy thresher (T_2), pedal operated paddy thresher (T_3) and traditional beating method (T_4) reveals that the mean threshing capacity of power operated paddy thresher (T_1) (375.25 kg/h) was highest and significantly different from all other methods when assessed at 5 % level of signficance. Lowest mean threshing capacity (193 kg/h) was observed in traditional method of threshing (T_4). When the increase in moisture content of grains, the threshing capacity was found to decrease. Further the combination of power operated paddy thresher at M1 moisture level (11.6 %) showed significantly high threshing capacity (400.5 kg/h). The unthreshed grain percentage which is desirable to be low was recorded to be minimum in traditional method (T_4) and hence greater grain recovery. The variation in threshing efficiency on changing grain moisture was found to be least. Although, highest threshing efficiency of 99.95 % was recorded in traditional method (T_4) and lowest (93.08 %) when threshing was done by handle operated paddy thresher (T_2). Further the data clearly indicates that all the threshing methods with the exception of power operated paddy thresher were at par with respect to cleaning efficiency.

556

A Study on Speed of Work and Output during Sustained Working of Mules: **R.L. Srivastava**, Animal Scientist (S. Gr.), AICRP on Animal Energy, College of Agricultural Engineering, Farm Machinery & Power Engineering Department, Allahabad Agricultural Institute, Deemed University, Allahabad-211007, India, **A.K.A. Lawrence**, Principal Investigator, same, **Shibbu Mathew**, Sr. Technical Assistant, same

Study was carried with two mules. It was found that speed of work was between 3.600 kmph to 4.390 kmph on 20 %, 25 % and 27 % draft load. Working speed of mule reduced with the increase in duration of work and draft level during winter, hot-humid and summer season. Power output of mule increase with increase in draft load between 0.648 kw to 0.981 kw but it was decreased with decrease in working speed of mule and also with increase in duration of work in winter, hot-humid and summer season.

■■

Book Review

Small Manufacturer's Toolkit

Author(s):

Stephen Novak - PPR Management Services LLC, Honolulu, Hawaii, USA

Detailed Description:

Small manufactures often lack the resources and expertise needed to choose the management philosophies and process improvement techniques that could provide the most benefit to their bottom line. Sorting through all of the available tools and deciding which ones to adopt can be overwhelming. The small Manufacturer's Toolkit: A Guide to Selecting the Techniques and Systems to Help You Win guides you through the philosophies that are constantly being promoted, enabling you make informed choices.

Following an introductory chapter, the author addresses fundamental inventory management and planning tools, including the Sales Operations Planning process that bridges the high-level strategic plan and the midrange master production schedule. The book then discusses Lean Manufacturing and the often accompanying Six Sigma, as well as the aspects of the Theory of Constrains that may cause confusion and prevent implementation.

The book reviews many of the most popular quality tools and quality management systems, fostering an understanding of what should be the foundation of any organization. The text also explores project management, and examines the requirements surrounding the implementation and use of ERP systems. It emphasizes awareness and application of Supply Chain Management techniques, and covers productive E-Commerce related applications. The book concludes by providing a diagnostic tool that helps you determine which tools, or aspects of tools, are valid for your organization.

UK Pond Price: 44.99

Published by:

Auerbach Publications (Taylor & Francis Group)

6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL 33487, USA

Handbook of Supply Chain Management 2nd Edition

Author(s):

James B. Ayers - CGR Management Consultants, Playa del Rey, California, USA

Detailed Description:

Supply chain management (SCM) disciplines have produced a flood of new concepts, methods, and tools; if applied wisely, they will improve results. A resource that weeds out and consolidates this new information will lower the business risk of implementing change.

Interpreting models and viewpoints from many fields into a supply chain context, Handbook of Supply Chain Management, Second Edition recommends a plan for acting on these insights, reducing confusion and making the work of supply chain managers both faster and more on target with the needs of their companies.

This volume introduces or emphasizes the supply chain management topics that have grown in visibility or prominence since the publication of the first edition.

These include: driver of supply chain change; project management approaches for executing supply chain change; globalization and supply chains; the importance of spheres (businesses within a business) in designing supply chain; the contribution of backbone/enabling process within an organization; and the "lean" and six sigma movements and their implications for SCM.

Divided into four parts, this volume begins by providing an overview that traces the evolution of concepts that define SCM. It then establishes the role of SCM in improving operations and the ability of businesses to compete.

Section II confronts management with "The Supply Chain Challenge," made up of five tasks that enable management to find solutions to problems and generate ideas for implementing a supply chain improvement project.

Section III describes how to perform critical supply chain improvement tasks, including activities that create a plan as well as tasks needed to implement the plan.

The book concludes with chapters devoted to case studies; each adds reality to theoretical frameworks. They illustrate successful and not-so-successful endeavors across the supply chain spectrum.

UK Pond Price: 44.99

Published by:

Auerbach Publications (Taylor & Francis Group)

6000 Broken Sound Parkway, NW, Suite 300, Boca Raton, FL 33487, USA

Maintainability Maintenance Reliability Engineers

Author(s):

Dr. B.S. Dhillon - University of Ottawa, Ontario, Canada

Detailed Description:

The demands of the global economy require manufacturers to produce highly reliable and easily maintainable engineering products. Recent studies indicate that for many large and sophisticated products or systems, maintenance, and support account for as much as 60 to 75 percent of their life cycle costs.

Therefore, the role of maintainability, maintenance, and reliability has become increasingly significant. Satisfying the pressing need for a volume that addresses these subjects with an interdiscilinary approach, Maintainability, Maintenance, and Reliability for Engineers distills knowledge specific to each discipline into one comprehensive resource.

After reviewing the history of art three fields and their interrelationships, the book covers mathematical concepts such as Boolean algebra Laws, probability properties, mathematical definitions, and probability distributions. It includes reliability evaluation methods such as fault tree analysis, network reduction method, delta-method, Markov method, supplementary variables method, and reliability management, both mechanical and human. Highlihting maintainibility tools and functions, the author discusses topics in maintainibility management and costing including tasks during product life cycle, program plan, organization functions, design reviews, life cycle costing, investment cost elements, and life cycle cost estimation models. The author also includes coverage of maintenance engineering, focusing on safety, quality, corrective, and preventive maintenance. The book concludes with coverage of maintenance management costing and human error in engineering maintenance and contains 60 illustrations, 16 tables, and more than 200 equations.

There is a definite need to considermaintainibility, maintenance, and reliability during product/system design and other phases. To achieve this goal effectively, it is absolutely imperative to have a certain degree of understanding of each of these disciplines. Although many books cover one or two of these topics, this is the first to cover all three in a manner useful to engineering professionals.

UK Pond Price: 56.99

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Reliability and Warranties

Author(s):

Prof. Marlin U. Thomas - Air Force Institute of Technology, Wright-Patterson AFB

Detailed Description:

Our modern view of quality is a multifaceted conglomeration of probability, planning, and perception. Although warranties are important first as an estimate and then as a measurement of reliability, most books on reliability and quality relegate the topic of warranties to a single chapter. Today's engineering student needs an integrated view that considers aft aspects that contribute to overall quality along with methods to analyze, predict, measure, and improve each component.

Reliability and Warranties: Methods for Product Development and Quality Improvement provides this unified treatment along with illustrative examples, end-of-chapter problems, and background material. Based on the author's distinguished experience as a practicing engineer and educator, this text supplies students with a modem education in quality engineering and the skills and knowledge necessary to succeed in the real world. It begins with preliminary results for dealing with failures followed by the modern definition and view of quality, various types and models for warranties, quality improvement, and perspective for achieving reliability and quality goals. It also includes a unique framework for measuring and tracking overall quality performance.

Ideal for senior undergraduate and first-year graduate students taking courses on quality, reliability, or industrial engineering, Reliability and Warranties presents a practical, thoroughly integrated path to meeting both engineering and customer quality goals.

UK Pond Price: 39.99

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Soil Erosion and Carbon Dynamics

Author(s):

Dr. Eric J. Roose - Laboratoire MOST LRD-CIRAD, Montpellier, France

Dr. Rattan Lal - Ohio State University, Columbus, USA

Dr. Christian Fetter - IRD - Laboratoire MOST, MontpeIIier, France

Bernard Barthes - IRD, Montepellier, France

Bobby A. Stewart - University of West Texas A&M University, Texas, USA

Detailed Description:

In addition to depleting nutrients necessary for healthy crops, soil erosion processes can affect the carbon balance of agroecosystems, and thus influence global warming. While the magnitude and severity of soil erosion are well documented, fluxes of eroded carbon are rarely quantified. The most complete, nonpartisan source of information available today on this topic, Soil Erosion and Carbon Dynamics brings together a diverse group of papers and data from the perspectives of world-renowned sedimentologists, soil scientists, and agronomists to resolve whether soil erosion on carbon is a beneficial or destructive process.

This book collects quantitative data on eroded carbon fluxes from the scale of the agricultural plot to that of large basins and oceans. It quantifies the magnitude of eroded carbon for different soil management practices as compared to normal carbon sequestration and discusses the fate of the eroded carbon and whether or not it is a source or sink for atmospheric CO^2. Finally, the book offers data reflecting the impact of soil erosion on soil, water, and air quality. Other important topics include solubilization, the determination of mineralization rates, carbon transfer, and sediment deposition, as well as carbon dioxide emissions, global warming potential, and the implications of soil erosion on the global carbon cycle and carbon budget.

Based on the first symposium of the international colloquium Land Uses, Erosion and Carbon Sequestration held in Montpellier, France, Soil Erosion and Carbon Dynamics provides data that links soil erosion to the global carbon cycle and elucidates the fate of eroded carbon at scales ranging from plot to watershed.

UK Pond Price: 74.99

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Climate Change and Global Food Security

Author(s):

Dr. Rattan Lal - Ohio State University, Columbus, USA

Norman Uphoff - Cornell University, Ithaca, New York, USA

Bobby A. Stewart - University of West Texas A&M University, Texas, USA

David O. Hansen - Ohio State University. Columbus, USA

Detailed Description:

In order to feed their burgeoning populations, developing nations will need to double cereal production by the year 2050. This increase will have to come from existing land, as little potential exists for bringing new land under cultivation - a daunting prospect when one realizes that increased use and significantly higher concentrations of carbon dioxide have led to a severe depletion of the carbon pool in the world's soils. This is especially telling in developing countries where tropical climates further compromise the soil's ability to recover.

In Climate Change and Global Food Security, bestselling editor Rattan Lal heads up a team of the world's top soil scientists and ecologists to document the history of this impending agricultural crisis and explore possible solutions. Throughout this timely text, the authors address six complex themes:

1. The impact of projected climate change on soil quality, water resources, temperature regime, and growing season duration on net primary productivity of different biomes
2. Soil carbon dynamics under changing climate
3. The impact of changes in carbon dioxide and ecological environments on agronomic yields and food production in different regions of the world
4. World food demands and supply during the 21st century
5. Policy and economic issues related to carbon trading and enhancing agricultural production
6. Research and development priorities for enhancing soil carbon pool and food security

This hard-hitting text is essential reading for anyone involved with soil and crop sciences as well as policy makers and change agents who need to come to the forefront of this issue armed with the latest information and viable solutions.

UK Pond Price: 79.99

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Handbook of Soil Acidity

Author(s):

Zdenko Rengel - University of WA, Australia

Detailed Description:

This handbook offers effective strategies to modify and adjust crop production processes to decrease the toxicity of soil contaminants, balance soil pH, improve root growth and nutrient uptake, and increase agricultural yield. The Handbook of Soil Acidity provides methods to, measure soil acidity, determine the major causes of soil acidification, calculate acidification rates for specific crop sequences, identify high-risk areas for soil acidification, and model acidification phenomena. This is an essential resource for plant, crop, soil, and environmental scientists, plant and crop physiologists, botanists, agronomists, agriculturists, and upper-level undergraduate, graduate, and continuing-education students in these disciplines.

UK Pond Price: 125.00

Published by:

Mercel Dekker, Inc.

270 Madison Avenue, New York, NY 10016, USA

Disassembly Modeling for Assembly, Maintenance, Reuse, and Recycling

Author(s):

A. J. D. Lambert - Technische Universiteit Einhoven, The Netherlands

Dr. Surendra M. Gupta - Northeastern University, Boston, Massachusetts, USA

Detailed Description:

Industry has grown to recognize the value of disassembly processes across a wide range of products. Increasing legislation that may soon require mandatory recycling of many post-consumed goods and a desire to develop more environmentally benign end-of-life processes has fueled research into this concept. Traditionally, disassembly has been viewed as the reverse of assembly; however, a novel view considers just the opposite, leading to a more optimized disassembly process.

Disassembly Modeling for Assembly, Maintenance, Reuse, and Recycling presents this approach in the context of the entire product life cycle. The book examines disassembly on the intermediate level, incorporating design for disassembly, concurrent design, and reverse logistics. In this first text to supply a comprehensive discussion of the theories and methodologies associated with this approach, the authors incorporate real world case examples to explore the three main areas of application of the theory: assembly optimization, maintenance and repair, and end-of-life processing.

This is a timely resource for companies that wish to enact environmentally conscious systems efficiently. With an analysis of associated costs, system design requirements, advantages, and expected results, this is also an indispensable tool for researchers, mechanical and industrial engineers, and professionals involved in concurrent design.

UK Pond Price: 48.99

Published by:

CRC Press

2000 N.W. Corporate Blvd., Boca Raton, Florida 33431, USA

Human Factors methods for Design: Making Systems Human-Centered

Author(s):

Dr. Christopher P. Nemeth - Consultant, Evanston, Illinois, USA

Detailed Description:

There is no shortage of available human factors information, but until now there was no single guide on how to use this information. Human Factors Methods for Design: Making Systems Human-Centered is an in-depth field guide to solving human factors challenges in the development process. It provides design and human factors professionals, systems engineers, and research and development managers with the orientation, process, and methods to perform human-centered research.

The book delivers an overview of human factors and the application of research to product and service development. It enables the reader to define a design opportunity, develop product goals, and establish criteria to meet those goals. The text offers a road map for correcting and analyzing human performance information, applying that information to the creation of solutions, and using the information to evaluate potential solutions.

The book demonstrates, in three sections, a way to design products that extend, amplify, and enhance human capabilities. Human Factors Practice explains research context including the operational environment and internal and external influences. Human Factors Methods explains how to perform a wide variety of procedures for human-oriented research and development. Application demonstrates how to put the results to use.

UK Pond Price: 62.99

Published by:

CRC Press

2000 N.W. Corporate Blvd., Boca Raton, Florida 33431, USA

Vibration and Shock Handbook

Author(s):

Dr. Clarence W. de Silva - University of British Columbia, Vancouver, Canada

Detailed Description:

Every so often, a reference book appears that stands apart from all others, destined to become the definitive work in its field. The Vibration and Shock Handbook is just such a reference. From its ambitious scope to its impressive list of contributors, this handbook delivers all of the techniques, tools, instrumentation, and data needed to model, analyze, monitor, modify, and control vibration, shock, noise, and acoustics.

Providing convenient, thorough, up-to-date, and authoritative coverage, the editor summarizes important and complex concepts and results into "snapshot" windows to make quick access to this critical information even easier. The Handbook's nine sections encompass: fundamentals and analytical techniques; computer techniques, tools, and signal analysis; shock and vibration methodologies; instrumentation and testing; vibration suppression, damping, and control; monitoring and diagnosis; seismic vibration and related regulatory issues; system design, application, and control implementation; and acoustics and noise suppression. The book also features an extensive glossary and convenient cross-referencing, plus references at the end of each chapter.

Brimming with illustrations, equations, examples, and case studies, the Vibration and Shock Handbook is the most extensive, practical, and comprehensive reference in the field. It is a must-have for anyone, beginner or expert, who is serious about investigating and controlling vibration and acoustics.

UK Pond Price: 99.00

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Rotordynamics

Author(s):

Dr. Agnieszka Muszynska - A.M. Consulting, Minden, Nevada, USA

Detailed Description:

As the most important parts of rotating machinery, rotors are also the most prone to mechanical vibrations, which may lead to machine failure. Correction is only possible when proper and accurate diagnosis is obtained through understanding of rotor operation and all of the potential malfunctions that may occur. Mathematical modeling, in particular modal modeling, is key to understanding observed phenomena through measured data and for predicting and preventing failure.

Rotordynamics advances simple yet adequate models of rotordynamic problems and phenomena related to rotor operation in its environment. Based on Dr. Muszy(n')ska's extensive work at Bently Rotor Dynamics Research Corporation, world renowned for innovative and groundbreaking experiments in the field, this book provides realistic models, step-by-step experimental methods, and the principles of vibration monitoring and practical malfunction diagnostics of rotating machinery. It covers extended rotor models, rotor/fluid-related phenomena, rotor-to-stationary part rubbing, and other related problems such as nonsynchronous perturbation testing. The author also illustrates practical diagnoses of several possible malfunctions and emphasizes correct interpretation of computer-generated numerical results.

Rotordynamics is the preeminent guide to rotordynamic theory and practice. It is the most valuable tool available for anyone working on modeling rotating machinery at the machine design stage or performing further analytical and experimental research on rotating machine dynamics.

UK Pond Price: 97.00

Published by:

Taylor & Francis Group

270 Madison Avenue, New York, NY 10016, USA

Standard Handbook of Chains: Chains for Power Transmission and Material Handling

Author(s):

American Chain Association - Naples,

Florida, USA
Detailed Description:
Since its founding, the American Chain Association (ACA) has set the standard of excellence in developing the chain industry and enhancing the benefit to customers. The first edition of Chains for Power Transmission and Material Handling served as the keystone reference to the field for more than twenty years. Fully updated with the Latest developments, the Standard Handbook of Chains: Chains for Power Transmission and Material Handling, Second Edition continues to build upon the more than 100 years of research and practical experience developed by the ACA.

This hands-on reference provides up-to-date guidance on the selection, design, utilization, and maintenance of various types of chains. It authoritatively covers the use of chains in various application environments, terminology, safety procedures, and the history of chains. The book features consistent selection guidelines to ensure a proper choice of chain every time. Updates include new information on chain design considerations, power ratings for roller and silent chains, and selecting drives with a life other than 15,000 hours. This edition includes an entirety new chapter on flat-top chain conveyors.

Including many helpful illustrations and a comprehensive troubleshooting table, the Standard Handbook of Chains: Chains for Power Transmission and Material Handling, Second Edition is the definitive handbook for anyone involved in the design, selection, use, and maintenance of all types of chains.
UK Pond Price: 79.99
Published by:
Taylor & Francis Group
270 Madison Avenue, New York, NY 10016, USA

Damage Mechanics

Author(s):
Prof. George Z. Voyiadjis - Louisiana State University, Baton Rouge, USA
Prof. Peter I. Kattan - Louisiana State University, Baton Rouge, USA
Detailed Description:
Before a Structure or component can be completed, before any analytical model can be constructed, and even before the design can be formulated, you must have a fundamental understanding of damage behavior in order to produce a safe and effective design. Damage Mechanics presents the underlying principles of continuum damage mechanics along with the latest research. The authors consider both isotropic and anisotropic theories as well as elastic and elasto-plastic damage analyses using a self-contained, easily understood approach.

Beginning with the requisite mathematics, Damage Mechanics guides you from the very basic concepts to advanced mathematical and mechanical models. The first chapter offers a brief MAPLE® tutorial and supplies all of the MAPLE commands needed to solve the various problems throughout the chapter. The authors then discuss the basics of elasticity theory within the continuum mechanics framework, the simple case of isotropic damage, effective stress, damage evolution, kinematic description of damage, and the general case of anisotropic damage. The remainder of the book includes a review of plasticity theory, formulation of a coupled elasto-plastic damage theory developed by the authors, and the kinematics of damage for finite-strain elasto-plastic solids.

From fundamental concepts to the latest advances, this book contains everything that you need to study the damage mechanics of metals and homogeneous materials.
UK Pond Price: 49.99
Published by:
Taylor & Francis Group
270 Madison Avenue, New York, NY 10016, USA

Wireless Sensor and Instruments: Networks, Design, and Applications

Author(s):
Dr. Halit Eren - Curtin University of Technology, Bentley, Western Australia
Detailed Description:
Advances such as 3-G mobile communications networks demonstrate the increasing capability of high-quality data transmission over wireless media. Adapting wireless functionality into Instrument and sensor systems endows them with unmatched flexibility, robustness, and intelligence. Wireless Sensors and Instruments: Networks, Design, and Applications explains the principles, state-of-the-art technologies, and modem applications of this burgeoning field.

From underlying concepts to practical applications, this book outlines all the necessary information to plan, design, and implement wireless instrumentation and sensor networks effectively and efficiently. The author covers the basics of instruments, measurement, sensor technology, communication systems, and networks along with the theory, methods, and components involved in digital and wireless instruments. Placing these technologies in context, the book also examines the principles, components, and techniques of modem communication systems followed by network standards, protocols, topologies, and security.

Building on these discussions, the book uses examples to illustrate the practical aspects of constructing sensors and instruments. Finally, the author devotes the closing chapter to applications in a broad array of fields, including commercial, human health, and consumer products applications.

Fined with up-to-date information and thorough coverage of fundamentals, Wireless Sensors and Instruments: Networks, Design, and Applications supplies critical, hands-on tools for efficiently, effectively, and immediately implementing advanced wireless systems.
UK Pond Price: 74.99
Published by:
Taylor & Francis Group
270 Madison Avenue, New York, NY 10016, USA

Co-operating Editors

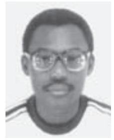

B Kayombo


M F Fonteh


A A K El Behery


A M El Hossary


B S Pathak


R J Bani


I K Djokoto


D K Some


K Houmy


J C Igbeka


E U-Odigboh


K C Oni


N G Kuyembeh


A H Abdoun


A B Saeed


A I Khatibu


E A Baryeh


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


A A Valenzuela


R Aguirre


O Ulloa-Torres


S G C Magana


H Ortiz-Laurel


W J Chancellor


M R Goyal


A K Mahapatra


G R Quick

S M Farouk

Daoulat Hussain

M A Mazed

M Gurung

Wang Wanjun

S Illangantileke

S M Ilyas

A M Michael

G Singh

T P Ojha

S R Verma

Soedjatmiko

M Behroozi-Lar

Saeid Minaei

J Sakai

B A Snorbar

C J Chung

C C Lee

M Z Bardaie

William J. Chancellor
Professor Emeritus, Bio. and Agr. Eng. Dept., Univ. of California, Davis, CA, 95616, U.S.A.
TEL+1-530-753-4292, FAX+1-530-752-2640
E-mail: wjchancellor@ucdavis.edu

Megh R. Goyal
Prof./Agric & Biomedical Engineering, University of Puerto Rico, P.O.Box 5984, Mayaguez PR, 006815984, U.S.A., TEL+1-787-265-4702
E-mail: m_goyal@ece.uprm.edu

Ajit K. Mahapatra
Present add: Agric. & Biosystems Eng. Dept., South Dakota State Univ., P.O. Box2120 Brookings, SD 57007-1496, U.S.A., TEL605-6885291, FAX 605-6886764, E-mail: mahapata@sdstate.edu

-ASIA and OCEANIA-

Graeme R. Quick
Consulting Enginner, 83 Morrisons Road, Peachester, Queensland, 4519, AUSTRALIA

Shah M. Farouk
Professor (Retd.),Farm Power & Machinery Dept., Bangladesh Agricultural University, Mymensingh 2200, BANGLADESH
TEL+880-91-5695ext.2596, FAX91-55810
E-mail: smf@bdcom.com

Daulat Hussain
Dean, Faculty of Agric. Engineering and Technology, Bangladesh Agricultural University, Mymensingh-2202, BANGLADESH
TEL+880-91-52245, FAX91-55810
E-mail: dhussain@royalten.net

Mohammed A. Mazed
Member-Director, Bangladesh Agri. Res. Council, Farmgate, Dhaka, BANGLADESH
E-mail: mamazed@barcbgd.org

Manbahadur Gurung
Store Officer, Bhutan Fruit Products Limited, Samtse, BHUTAN, TEL+975-65369

Wang Wanjun
Past Vice Director and Chief Engineer/Chinese Academy of Agricultural Mechanization Sciences, 1 Beishatan, Beijing, 100083, CHINA
TEL+86-(0)83-001-6488-2710, FAX001-6488-2710
E-mail: wwj@isp.caams.org.cn

Sarath Illangantileke
Regional Representative for South and West Asia, International Potato Center (CIP), Regional Office for CIP-South & West Asia, IARI (Indian Agric. Res. Institute) Campus, Pusa, New Delhe-12, 110002, INDIA
TEL+91-11-5719601/5731481, FAX./5731481
E-mail: cip-delhi@cgiar.org

S.M. Ilyas
Director of Central Institute of Post Harvest Engineering and Technology (CIPHET), Ludhiana. P.O., P.A.U, Ludhiana - 121004, INDIA, Tel+91-161-808669, Fax:+91-161-808670, E-mail: ciphet@satyam.net.in

A.M. Michael
1/64, Vattekunnam, Methanam Road, Edappally North P.O., Cochin, 682024, Kerala State, S. INDIA

Gajendra Singh
Professor, AFE Program, Asian Institute of Technology, P.O. Box 4, Klongluang, Pathumthani 12120, THAILAND

T.P. Ojha
Director General(Engg.) Retd., ICAR, 110, Vineet Kung Akbarpur, Kolar Road, Bhopal, 462 023, INDIA
TEL+91-755-290045

S.R. Verma
Prof. of Agr. Eng, & Dean Eng.(Retd), 14, Good Friends Colony, Barewal Road , Via Ayoli Kalan, Ludhiana 142027 Punjab, INDIA, TEL+91-(0)161-463096
E-mail: srverma@hotmail.com

Soedjatmiko
President, MMAI(Indonesian Soc. of Agric. Eng. & Agroindustry), Menara Kadin Indonesia Lt.29 Jl. HR. Rasuna Said X-5/2-3 Jakarta, 12940, INDONESIA
TEL+62-(0)21-9168137/7560544, FAX(0)21-527448 5/5274486/7561109

Mansoor Behroozi-Lar
Professor, Agr. Machinery, Ph.D, Tehran University Faculty of Agriculture, Karaj, IRAN
TEL+98-21-8259240, E-mail: mblar@chmran.ut.ac.ir

Saeid Minaei
Assistant Professor, Dept. of Agr. Machinery Eng., Tarbiat Modarres Univ., P.O.Box 14115-111, Tehran, IRAN
TEL+9821-6026522-3(office ext.2060, lab ext.2168)
FAX+9821-6026524, E-mail: minaee7@hotmail.com

Jun Sakai
Professor Emeritus, Kyushu University, 2-31-1 Chihaya, Higashi-ku, Fukuoka city, 813, JAPAN
TEL+81-92-672-2929, FAX+81-92-672-2929
E-mail: junsakai@mtj.biglobe.ne.jp

Bassam A. Snobar
Professor and Vice President, Jordan University of Science and Technology, P.O.Box 3030 Irbid, 22110, JORDAN, TEL+962-2-295111, FAX+962-2-295123
E-mail: snobar@just.edu.jo

Chang Joo Chung
Emeritus Professor, Seoul National University, Agricutural Engineering Department, College of Agriculture and Life Sciences, Suwon, 441-744, KOREA
TEL+82-(0)331-291-8131, FAX+82-(0)331-297-7478
E-mail: chchung@hanmail.net

Chul Choo Lee
Mailing Address: Rm. 514 Hyundate Goldentel Bld. 76-3 Kwang Jin Ku,Seoul, KOREA
TEL+82-(0)2-446-3473, FAX+82-(0)2-446-3473
E-mail: ccsslee@chollian.net

Muhamad Zohadie Bardaie
Professor and Deputy Vice Chancellor (Development Affairs), Chancellory, Universiti Putra Malaysia, 43400 UPM, Serdang, Selangor, Darul Ehsan, MALAYSIA
TEL+60-3-9486053, FAX3-9426471
Email: mzbd@admin.upm.edu.my

Madan P. Pariyar
Consultant, Rural Development through Selfhelp Promotion Lamjung Project, German Technical Cooperation. P.O. Box 1457, Kathmandu, NEPAL

David Boakye Ampratwum
Associate Professor, Dept.of Bioresource and Agricultural Engineering, College of Agriculture, Sultan Qaboos University, P.O. Box 34, Post Code 123, Muscat, Sultanate of Oman, OMAN
TEL+968-513866, FAX513866
E-mail: davidamp@squ.edu.om

EITag Seif Eldin
Mailling Address: Dept. of Agric. Mechanization, College of Agriculture, P.O. Box 32484, Al-Khod, Sultan Qaboos University, Muscat, Sultanate of Oman, OMAN

Linus U. Opera
Associate Professor, Agricultural Engineering & Postharvest technology, Director, Agricultural Experiment Station, Sultan Qaboos University, Muscat, Sultanate of Oman, OMAN

Allah Ditta Chaudhry
Professor and Dean Faculty of Agric. Engineering and Technology, University of Agriculture, Faisalabad, PAKISTAN


M P Pariyar

D B Ampratwum

E S Eldin

L U Opera

A D Chaudhry

A Q Mughal

R ur Rehmen

B T Devrajani

N A Abu-Khalaf

Surya Nath


R M Lantin


R P Venturina


S A Al-Suhaibani


A M S Al-Amri


S F Chang


T S Peng


S Krishnasreni


S Phong-supasamit


C Rojanasaroj


V M Salokhe


Y Pinar


I Haffar

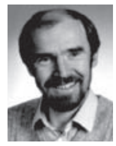

N Hay


P V Lang


A A Hazza'a


A P Kaloyanov


P Kic


H Have


G Pellizzi


A A Wanders

A.Q.A. Mughal
Vice Chancellor, Sindh Agriculture University, Tandojam, PAKISTAN

Rafiq ur Rehman
Director, Agricultural Mechanization Reserch Institute, P.O. Box No. 416 Multan, PAKISTAN

Bherulal T. Devrajani
Professor and Chairman, Faculty of Agricultural Engineering, Sindh Agriculture University, Tandojam, Sindh, PAKISTAN
TEL+92-2233-5594

Nawaf A. Abu-Khalaf
Engineer, the Project Directorate in Palestinian Agricultural Ministry, P.O.Box 405, Hebron, PALESTINE
Telfax: 972-2-2227846/7
E-mail: nawafu@hotmail.com

Surya Nath
Associ. Prof., Dept. of Agriculture, Papua New Guinea University of Technology, Private Mail Basg, Lae, PAPUA NEW GUINEA, TEL+675-475-5162, FAX473-4477, E-mail: Nath@datec.net.pg

Reynaldo M. Lantin
Professor, College of Engineering and Agro-Industrial Technology University of the Philippines Los Banos, Laguna 4031, PHILIPPINES
TEL+63-(0)49-536-2792, FAX+63-(0)49-536-2873
E-mail: rmlantin@mudspring.uplb.edu.ph

Ricardo P. Venturina
President & General Manager, Rivelisa publishing House, 215 F, Angeles St. cor Taft Ave. Ext., 1300 Pasay City, Metro Manila,PHILIPPINES

Saleh Abdulrahman Al-suhaibani
Professor, Agricultural Engineering Dept.,College of Agriculture, King Saud University,P.O. Box 2460 Riyadh 11451, SAUDI ARABIA

Ali Mufarreh Saleh Al-Amri
Professor, Dept. of Agric. Engineering, Colleg of Agricultural and Food Sciences, King Faisal University, Al-Ahsa,SAUDI ARABIA
E-Mail: aamri@kfu.edu.sa,aamri2020@yahoo.com

Sen-Fuh Chang
Professor, Agric.-Machinery Dept. National Taiwan University, Taipei, TAIWAN

Tieng-song Peng
Deputy Director, Taiwan Agricultural Mechanization Research and Development Center. FL. 9-6, No. 391 Sinyi Road, Sec. 4, TAIWAN

Suraweth Krishnasreni
Senior Expert in Agricultural En-gineering, Department of Agricul-ture, Chatuchak, Bangkok 10900, Thailand, Tel5792153,5794497,5798520,Ext.124, Fax9405791, E-mail: Suraweth@doa.go.th

Surin Phongsupasamit
Professor of Agricultural Engineering, Dept. of Mechanical Engineering, Faculty of Engineering, Chulalongkom University, Phyathai Road, Patumwan, Bangkok 10330, THAILAND

Chanchai Rojanasaroj
Research and Development Engineer, Dept. of Agriculture, Ministry of Agriculture and Cooperatives, Gang-Khen, Bangkok 10900, THAILAND

Vilas M. Salokhe
Professor, AFE Program, Asian Institute of Technology, P.O. Box 4, Klang Luang. Pathumthani 12120, THAILAND, TEL+66-2-5245479, FAX+66-2-5246200
E-mail: salokhe@ait.ac.th

Yunus Pinar
Professor, and Head, Agric. Machinery Dept, Faculty of Agriculture, University of Ondokuz Mayis, Kurupelit, Samsun, TURKEY

Imad Haffar
Associate Professor of Agric. Engineering, Faculty of Agricultural Sciences, United Arab Emirates University, Al Ain, P.O. Box 17555, UAE
TEL+971-506436385, FAX+971-3-632384
E-mail: haffar96@emirates.net.ae

Nguyen Hay
Associate Professor, Dean of Faculty of Engineering, Nonglam University, Linh Trung Ward, Thu Duc District, Ho Chi Minh City, VIET NAM
E-mail: nguyenhay@hcm.fpt.vn

Pham Van Lang
Director, Vietnam Institute of Agricultural Engineering, A2-Phuong Mai, Dong Da Hanoi, VIET NAM

Abdulsamad Abdulmalik Hazza'a
Professor and Head of Agricultural Engineering Department, Faculty of Agriculture, Sana'a University, P.O.Box 12355, Sana'a YEMEN
Tel+9671-407300, Fax:9671-217711
E-mail: hazaia@yahoo.com

-EUROPE-

Anastas Petrov Kaloyanov
Professor & Head, Research Laboratory of Farm Mechanization, Higher Institute of Economics, Sofia, BULGARIA

Pavel Kic
Vice-Dean/Technical Faculty, Czech University of Agriculture Prague, 16521 Prague 6-Suchdol, CZECH, Tel+420-2-24383141, Fax+420-2-20921361
Email: KIC@TF.CZU.CZ

Henrik Have
Prof. of Agric. Machinery and Mechanization at Institute of Agric. Engineering, Royal Veterinan/- and Agricultural University, Agrovej 10DK2630 Tastrup, DENMARK

Giuseppe Pellizzi
Director of the Institute of Agric. Engineering of the University of Milano and Professor of Agric. Machinery and Mechanization, Via G. Celoria, 2-20133 Milano, ITALY
Tel+39-02-503-16871, Fax+39-02-503-168459
E-mail: giuseppe.pellizzi@Unimi.it

Aalbert Anne Wanders
Staff Member, Dept. of Development Cooperation, Netherlands Agricultural Engineering Research Institute (IMAG), Wageningen, NETHERLANDS

Jan Pawlak
Professor, head of the Dept. of Economics and Utilization of Farm Machines at IBMER, Professor at the Univ. of Warmia and Mazury in Olsztyn, Fac. of Tech. Sci., POLAND

Oleg S. Marchenko
Professor and agricultural engineer, Department Head in All-Russia Research Institute for Mechanization in Agriculture (VIM), 1st Institutsky proezd, 5, Moscow 109428, RUSSIA
Tel+7(095)174-8700, Fax+7(095)171-4349
E-mail: oleg072000@mail.ru

John Kilgour
Senior Lecturer in Farm Machinery Design at Silsoe College, Silsoe Campus, Silsoe, Bedford, MK45 4DT, UK

Milan Martinov
Full Professor on Agricultural Machinery, University of Novi Sad, Faculty of Engineering, Institute of mechanization and machine design, TRG D. Obradovica 6, 21 121 Novi Sad, PF55, YUGOSLAVIA
TEL+381-21-350-122(loc.298), FAX+381-21-350-592
E-mail: mmartog@uns.ns.ac.yu


Jan Pawlak


O S Marchenko


J Kilgour


M Martinov

Back Issues

(Vol.34, No.3, Summer, 2003-)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol.36, No.1, Spring, 2005)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol.36, No.2, Autumn, 2005)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol.37, No.1, Winter, 2006)

■■