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YOSHISUKE KISHIDA

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

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EDITORIAL

Impact of China

The world population has broken through 6 billion and continues to grow at the rate of 0.1 billion a year. Whether we can supply all the population with enough food will be the most critical issue in the 21st century. Especially in the countries with huge populations such as in India and China, food problem is the most essential and top priority subject. In China, with the world's largest population as many as 1.3 billion, agriculture is the most important industry. On the other hand, China is seeking a way to join the world market and positively considering to be a member of WTO, which is likely to materialize in the near future. However, that policy in China is causing a new problem in the agricultural sector. China has put much importance to agriculture and taken the policy to protect domestic agriculture in favor of the average small-scale farmers. Under that system grains are purchased by the government at controlled prices. As a result, grain stock is increased and grain price remains higher than that of international price.

If China joins WTO and agricultural products are subject to free trade, domestic production of Indica rice, wheat, soybean and corn will be hit by import products. Only Japonika type rice and vegetables will remain competitive items. China wants to increase the export of those items to Japan.

Considering that nearly 70 percent of the population live in rural areas, the economic gap between rural area and coast area will further expand with China's joining the WTO. The liberalization of prices of agricultural products has already brought about a sharp decline in the price of agricultural products. It can easily be figured out that farmers in the inland areas will suffer from poverty as a result. That will raise a new political problem in China.

That is not the only case in China, but most of small-scale farmers, especially in developing countries, will be hit hard by a drop in agricultural products price under a free trade system. Many farmers will have no choice but to give up agriculture and move to urban areas to make a living. That will be a large damage to the entire ecological system from a global point of view. The author is much concerned about where we will be landing on.

To keep an appropriate price of agricultural products it is essential to promote agricultural mechanization. It is ideal that consumers pay a little more for agricultural products but that seems very difficult under present free market system.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
April 2001

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
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A Twin-Purpose, Light Weight New Iron Plough

by
R.Kailappan
Professor & Head
Scientists of Regional Research Station,
Tamil Nadu Agricultural University,
Paiyur - 635 112.
Tamil Nadu, India.

A. K. Mani
Scientists of Regional Research Station,
Tamil Nadu Agricultural University,
Paiyur - 635 112.
Tamil Nadu, India.

R.Rajagopalan
Scientists of Regional Research Station,
Tamil Nadu Agricultural University,
Paiyur - 635 112.
Tamil Nadu, India.

Abstract

A new twin-purpose, light weight iron plough suitable for small animals capable of doing dry ploughing (throwing the furrow slice on both sides) and wet land puddling (complete inversion of furrow slice) by simply changing the plough bottom with the help of two bolts and nuts has been fabricated and field tested. The plough is simple in construction, works on the principle of suction rather than dead weight of the plough. It covers about 0.4 ha per day of eight hours. The approximate cost of the plough is $12.00.

Introduction

Agriculture is the way of life for 70% of the Indians in the rural areas. Partial mechanization of agriculture will promote higher productivity and better quality produce. Land preparation is the first and important operation which should be done in a proper way to get better yield. At present, the farmers are using wooden country ploughs and iron ploughs for this purpose. There are 44.16 million wooden country ploughs and 12.72 million iron ploughs in use throughout the country (Anon, 1997). But the life span of these ploughs vary from 1-1.1/2 years in the case of wooden country ploughs and 2 - 3 years for iron ploughs. Moreover, these ploughs require heavy weight draft animals to carry out the operation. In some economically backward drought areas like Dharmapuri district in Tamil Nadu, farmers are using small cows (each animal weighing 150 - 175 kg) both for draft and milk purposes. They are using small, very crude shaped wooden country ploughs for ploughing and "worn-out" (smaller size) wooden country ploughs for puddling. The ploughs found in other parts of the country are heavy for the animals and costly for the peasants of this region. Both farmers and animals of this region, require a special, small, scientifically made plough to meet their requirements. Hence, a twin-purpose, light weight, iron plough suitable for small draft cows / bullocks of this region has been developed at the Regional Research Station, (a sub-station of Tamil Nadu Agricultural University, Coimbatore, India) Paiyur, located in this area.

Acknowledgement: The authors express their sincere thanks to Dr. P. Duraisamy, Mr.Krishnan (Mechanic), Mr.Palani Kannu and farmers for their help during evaluation of the plough.

Manufacturing Details of New Iron Plough

The new twin-purpose, light weight iron plough consists of the following parts (**Figure 1**): handle cum-heel of the plough; inter-

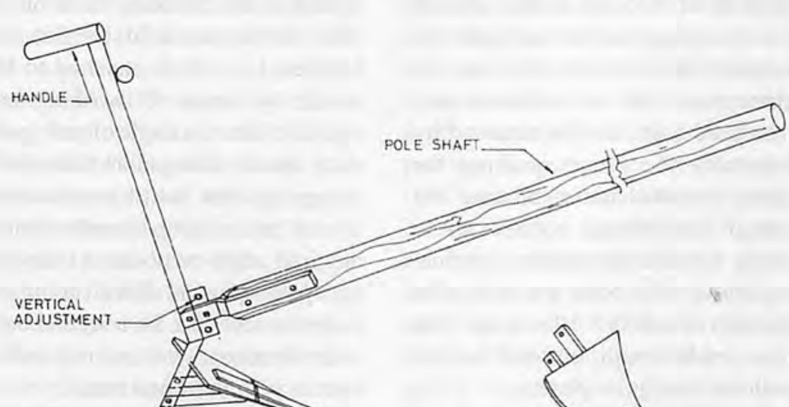

Fig. 1 The twin-purpose, light weight new iron plough.

Table 1. Comparison of New Plough with Existing Ploughs

Particulars	New plough	Existing ploughs	
		Country	Melur
Cost ($)	12.0	3.0 - 5.0	5.0
Expected life(years)	15	1-1.1/2	4-5
Average coverage (ha/day)			
a) Dry ploughing	0.44 - 0.48	0.35 - 0.40	-
b) Wet puddling	0.42 - 0.44	-	0.30-0.32
Average time required to plough one ha			
a) Dry ploughing	17 h 9 min.	20 h 38 min	-
b) Wet puddling	18 h 48 min	-	25 h 31 min.
Average saving in time (%)			
a) Dry ploughing	17.4	-	-
b) Wet puddling	24.4	-	-
Cost of ploughing per ha($)			
a) Dry ploughing	3.72	4.50	-
b) Wet puddling	4.17	-	5.51
Average saving in cost (%)			
a) Dry ploughing	22.0	-	-
b) Wet puddling	25.9	-	-
Average draft (kg)			
a) Dry ploughing	36	46	-
b) Wet puddling	31	-	36

Fig. 2 The twin-purpose plough in action.

changeable plough bottoms; clamps; and pole shaft.

The plough has been fabricated with mild steel flat having a cross section of 38 × 10 mm size and 8 mm thick mild steel plate. The handle cum-heel of the plough is made of mild steel flat of 850 mm length, partially cut and bent at a distance of 200 mm from the plough heel. Among the two plough bottoms, one plough bottom is made of 390 × 390 × 220 mm size 8 mm thick mild steel triangular plate with 300 × 38 × 10 mm size mild steel flat sharpened at one end and fixed on the top of the triangular plate as a bar share by means of a clamp. This serves the purpose of wooden country plough i.e., to open a furrow and push the furrow slice on both sides. As the share wears due to continuous use, the share point can be renewed by loosening the clamp, pushing the share forward and tightening the clamp. This plough bottom can be easily fitted to the handle cum-heel rigidly by two bolts and nuts with the help of two 38 × 10 mm size flats of suitable length, cut and welded with the triangular plate.

The other one is a mould board plough like plough bottom, which is also made of 8 mm thick mild steel plate having a width of cut of 150 mm and bent suitably so that it can cut, lift, invert and throw the furrow slice to one (right) side of the plough. The tip of the mould board has been cut and a 300 × 38 × 10 mm size mild steel flat sharpened at one end has been introduced and fixed with the help of a clamp in an adjustable manner. By means of 38 × 8 mm cross sectional size mild steel flat of suitable length, this mould board plough like plough bottom can be fixed to the handle cum-heel, by removing wooden country plough like plough bottom.

The pole-shaft of the plough, a casuarina round pole, having a length of 2.5 m and 75 mm diameter has been connected to the handle by means of two brackets made out of 38 × 10 mm size mild steel flat. The brackets have been attached to the handle by means of two bolts and nuts such that the angle of pull / pole shaft can be changed as follows: a) loosen the first bolt; b) remove the second bolt; c) keep the pole shaft at required angle or position (depending upon the height of draft animals); d) drill a new hole for a second bolt; refix the second bolt and nut; and e) tighten both bolts and nuts.

The pole shaft has been attached to the brackets rigidly by means of two bolts and nuts having a centre to centre distance of 170 mm. With this arrangement, the possibility of breaking the pole shaft during ploughing by way of hitting of share either with rock or roots of a tree etc., is remote. As all the plough components are made up of mild steel material and of required size, breaking of components will not occur during operation. The only fast wearing part in the plough is the bar share which can be renewed easily, as explained earlier.

The plough has a weight of 13.5 to 14 kg and costs only $12.00 with both plough bottom attachments. In this region, the farmers use wooden country plough which costs $3 to 5 (depending upon the tree and size selected) for dry ploughing. The life of this plough is 1-1.1/2 years. A country plough weighs approximately 15 kg. For wetland puddling in this region an iron framed cost iron mould board plough is used. The weight of this plough is 10-12 kg. The cost of the plough is about $5.00. This plough is made up cast iron and breaks easily if the plough touches a rock or root. As the size of the existing iron mould board plough in other regions is big and weighs about 20 kg, no farmers of this region uses iron mould board ploughs including improved ploughs, available in other parts of the country.

(Continued on page 18)

Wear Characteristics of the Ghanaian Hand Hoe

by
E.A. Baryeh
Professor
Agricultural Engineering Department
University of Cape Coast
Cape Coast
Ghana

Abstract

The wear of the Ghanaian hand hoe was investigated by varying a number of parameters. The hoes were tested in a rotating laboratory soil bin using loamy soil and soils with various percentages of gravel content. It was found that the wear, in terms of weight and dimensional loss of hoe, increased with an increase in soil moisture content, operation speed, hoe operation angle and time of operation. Relations of the form:

$\Psi = Ae^{\alpha t} + \beta$

and

$\Psi = kt^n$

were found to exist between wear and operation time. Wear variation with soil moisture content was linear, while the variation with operation speed and hoe operation angle were non-linear. The rate of wear was maximum at 67.5 hours operation in all cases. Wear rate increased with increasing gravel aggregate up to 22% gravel after which the wear rate was practically constant with increasing gravel aggregate.

Introduction

Hand hoes are used in Ghana and other developing countries for land clearing, mechanical weed control, digging holes and shallow trenches, and making mounds and beds for agricultural production. The hoe is, therefore, a principal manual tillage tool of the Ghanaian small farmers. Some medium-size farmers and large commercial farmers, however, employ general purpose mouldboard ploughs for their tillage needs.

The hoes used by farmers are fabricated from scrap metals by local artisans. Some of those hoes wear out fast partly because they are fabricated from improper materials and partly because of the abrasive nature and condition of some of the soils they work. The mechanical properties of these scrap metals are generally below acceptable levels due to their rusty nature, inconsistent composition and high rate of wear (Intermediate Technology,1992).

The wear of hoes leads to frequent stoppage of work to resharpen or replace them (Baryeh, 1997). This further leads to loss of time, especially during peak seasons. This eventually results in a disorganisation of the timing of the cultivation process, and consequently, to low yield and financial loss.

Ferguson, Fielke and Riley (1998) and Miller (1984) found soil moisture content and soil aggregate affect cultivator shares in some soils in Australia, while Singh, Shukla and Singh (1993) found the wear of reversible shovels to be dependent on material of manufacture of shovels and soil type. The wear of the Ghanaian hand hoe is dependent on hoe material, soil type and depth of operation (Baryeh, 1997) who has conducted studies on the wear of the Ghanaian hand hoe in which soil moisture content, hoe operation angle and operation speed were fixed. The work presented here has taken the previous study further by evaluating the wear of the hoe at different soil moisture contents, hoe operation angles, operation speeds, and of the soil gravel content percentage.

Materials and Methods

The hoe dimensions and circular rotating wooden trough and power drive assembly used for the tests are as described in previous tests (Baryeh, 1997). Previous investigations by the author reveal that heat treated mild steel exhibited the most desirable wear characteristics. This material was, therefore, selected for the manufacture of the hoes used for the study. Different size pinions used on the drive from the electric motor to the trough enabled the speed of rotation of the trough to be varied. The hoe operation depth was kept at 100 mm because previous investigation by Baryeh (1997) has considered other depths. This is also the usual tillage depth of hand hoes. Loamy soil was used for most of the tests and a series of tests were also conducted using soils of different percentages of gravel aggregates. The trough speeds used were 2, 5 and 8 km/h, which are normal tillage speeds. Soil moisture contents used were 10, 20 and 30%(db) which are common in the humid rain forest region of Ghana. Hoe inclination angles, i.e., angle between the soil surface and plane of hoe of 30^0, 45^0 and 60^0 were used. Percent gravel was obtained by sieving the aggregates to obtain particles with a maximum linear dimension of 3 mm or higher. Weight and dimensional loss of hoe were determined and used as a measure of wear. The hoe dimensions monitored were the height, h and the width, w (see **Figure 1**).

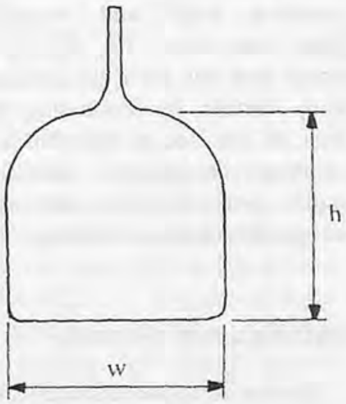

Fig. 1 Handhoe showing depth and width dimensions.

Results and Discussion:

Figure 2 shows the variation of the cumulative wear of the hoe with respect to time of operation for different soil moisture contents when the hoe operation angle and speed of operation are fixed. **Figure 3** shows the wear variation with soil moisture for different operation times when hoe operation angle and speed of operation are fixed. The figures reveal that the wear increased with increasing soil moisture content as well as increasing operation time. The increase of wear with operation time is non-linear while the increase with soil moisture is linear for the operation speeds. The difference in wear between the moisture contents increased with increasing operation time while the difference in wear between operation times also increased with an increasing moisture content. The study also reveals that wear of tillage tools increase non-linearly with operation time or distance of operation (Ferguson, Fielke and Riley, 1998; Foley, Chisolm, and McLees, 1988; Miller, 1984; Singh, Shukla and Singh, 1993). Other researchers have also found that the wear of tillage tools increase with soil water content (Yu and Bhole, 1990). The results, however, contrast with those of Ferguson, Fielke and Riley (1998) and Quick and Woods (1979) who found that the wear decreased with soil moisture in some Australian soils. According to Ferguson, Fielke and Riley (1998) all the results, in effect, are correct because the tests by Miller (1984) have shown that the effect of soil water content on the wear rate of tillage tools is dependent on soil type, being different for sandy soils as compared with clay soils. Wear tends to increase with soil moisture content in sandy soils and decrease with soil moisture content in clayey soil (Ferguson, Fielke and Riley, 1998; Miller, 1984). The present study reveals an increase of wear with soil moisture content in loamy soil where the rate of increase in loamy soil is lower than that of sandy soil but higher than that of clayey soil when other parameters are fixed. This conclusion is made by referring to **Figure 4** which has combined the results obtained by Ferguson, Fielke and Riley (1998), Miller (1984) and the results of the present study. Ferguson, Fielke and Riley (1998) further observed a change in the location of wear when soil moisture was increased from 2 to 18%(db). This phenomenon was not observed in the present study. Wear of surfaces depends, among others, on surface topography (Gahr, 1987; Suh, 1988) and this could be responsible for the differences in location of wear. From the results it is advisable to till the land at low moisture content at the beginning of the rains when moisture content is usually between 5% and 15%.

The wear was found to increase with speed and time of operation as shown in **Figures 5** and **6**. **Figure 5** exhibits a non-linear relationship

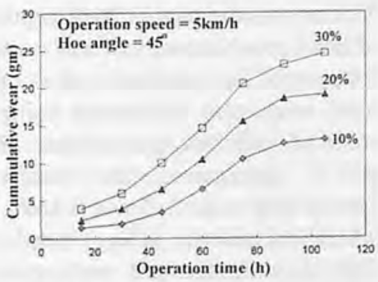

Fig. 2 Variation of wear with operation time for different soil MC level.

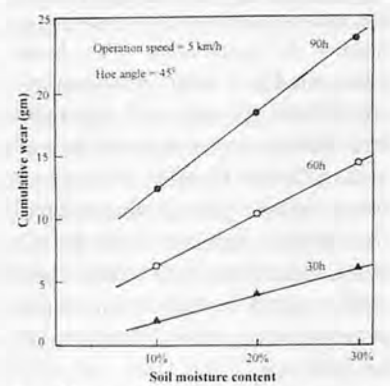

Fig. 3 Variation of wear with soil moisture content for different operation times.

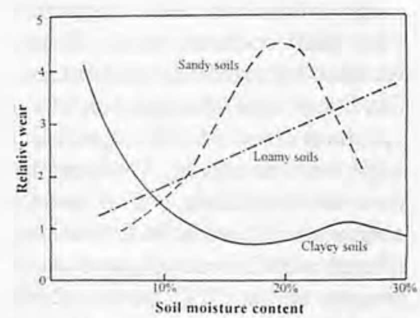

Fig. 4 Effect of MC level on wear rate.

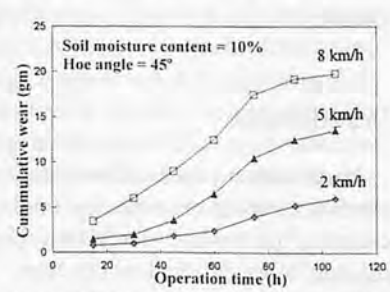

Fig. 5 Variation of wear with operation time for different operation speeds.

while **Figure 6** is approximately linear. Again, difference in wear between operation speed increased with increasing operation time, and difference in wear between operation times increased with increasing operation speed. Other researchers have confirmed this result (Quick, Woods and Bartlett, 1979; Schefler and Allen, 1988). Tribological theory also confirms that the wear of metals generally increase with speed of rubbing surfaces, and the wear becomes both abrasive and erosive at high rubbing speeds (Czichos, 1978; Gahr, 1987 and Suh, 1988). Tilling at low speed is hence recommended for low wear. This means longer times for tillage which can be a problem if the rains start late making it necessary to till in a shorter time. The farmer, therefore, has to compromise between speed and wear when the rains start late in order to plant at the right time.

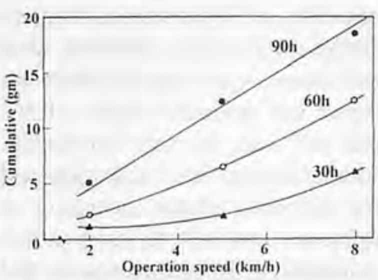

Fig. 6 Variation of wear with operation speed for different operation times.

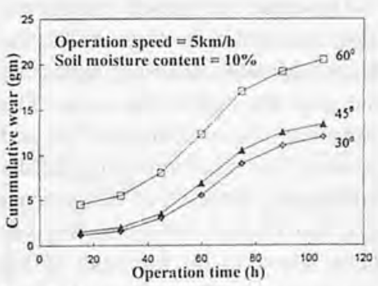

Fig. 7 Variation of wear with operation time for different hoe angles.

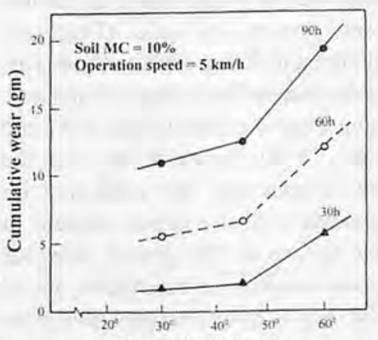

Fig. 8 Variation of wear with hoe angles for different times.

Figures 7 and **8** depict an increase in wear with an increase in hoe operation angle and operation time. The difference in wear between hoe operation angle increased with an increasing operation time but difference in wear between operation times did not change appreciably with increasing hoe operation angle. The increase was very gentle up to 45^0 and very acute above 45^0 for the operation times. This is because as the angle of operation with the soil surface increased, the hoe got closer to vertical operation and the soil compacted as the tool engaged it offering more resistance and thereby imparting more wear to the tool. When the angle is small, the tool tends to scrape the soil surface instead of digging into it, encountering less resistance and hence less wear. It is recommended that the hoe operation angle be kept around 45^0.

The cumulative wear was generally low in the first 30 hours of operation after which the wear increased rapidly up to 75 hours then it became slow again. This behaviour has been explained in previous studies (Baryeh, 1997).

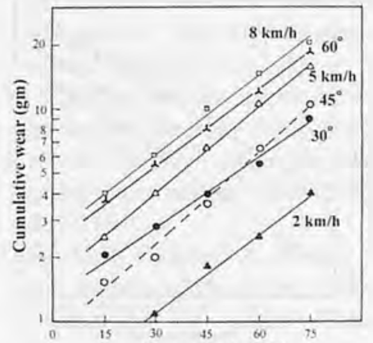

Fig. 9 Variation of wear with operation time (semi-log sheet).

The cumulative wear variation with time plot linearly up to 75 hours operation on linear-log sheet as indicated in **Figure 9**. The slopes of the lines are not the same. Nevertheless, this means that for this range, the wear can be predicted by an equation of the form:

$$\Psi = Ae^{\alpha t} + \beta$$

where,

Ψ = cumulative wear (gm)

t = operation time (h)

A, α and β = constants depending on soil moisture content, operating speed and hoe operation angle. These constants can be determined experimentally and by regression analysis

Figures 10, **11** and **12** show the rate of wear variation with operation time for varying soil moisture content, varying hoe operation angle and varying operation speed, respectively. The wear rate increased with operation time for all the soil moisture contents considered peaking at 67.5 hours (**Figure 10**). After that the rate decreased. There were substantial differences in the rates between the various moisture contents when the operation time was less than or equal to 67.5 hours. After 67.5 hours, the wear rates are not very different. The rates were highest for 30% moisture content and lowest for 10% moisture content (**Figure 10**). **Figure 12** shows that the rate increased with increasing the operation speed peaking again at 67.5 hours. Such increase was found by other researchers but without any peaking (Quick, Woods and Bartlett, 1979). After the peaking there was very little difference between the rates for 5 and 8 km/h operation speed, but there was still substantial difference between 2 and 5 km/h. **Figure 11** indicates that there was very little difference in the wear rate for hoe operation angles of 30^0 and 45^0. The difference, however became substantial when the angle was increased to 60^0. The rate increased with an increase in hoe operation angle peaking at 67.5 hours. The results indicate that it is not advisable to operate the hoe at angles higher than 45^0.

In general, hoe dimensions, h and w, **Figure 1**, decreased with an increasing soil MC level, increasing operation speed, increasing hoe operation angle, and increasing operation time. The reduction in h was

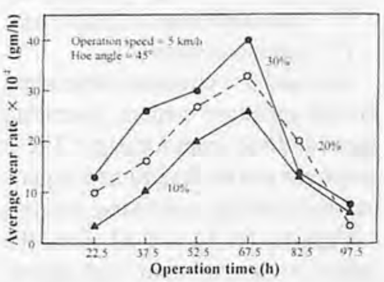

Fig. 10 Wear rate variation with operation time for different moisture content.

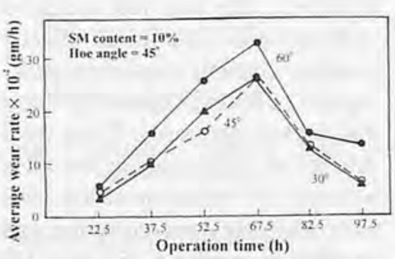

Fig. 11 Wear rate variation with operation time for different operation speeds.

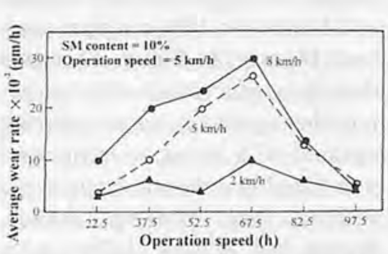

Fig. 12 Wear rate variation with operation time for different hoe angles.

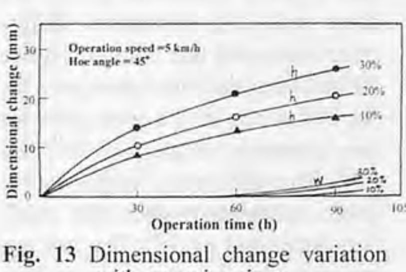

Fig. 13 Dimensional change variation with operation time.

much higher than w for all situations. Typical dimensional change variation with time of operation as shown in **Figure 13** for different MC level. In general, the change in w was negligible while the change in h was substantial. The curves for h are evenly spaced as they fan out from the origin indicating that the dimensional loss in h varies linearly with MC level. The curves for w do not show such linear variation. The pattern was similar when plotted (not shown), for varying operation speeds and varying hoe operation angles, except that the dimensional loss in h varied nonlinearly with both operation speed and hoe operation angle. The reduction in h with operation time plot linearly on log-log sheet for fixed operation speed and hoe operation angle as shown in **Figure 14** for the three soil MC levels. The lines for the various MC levels were parallel to each other. Those for variation of h with operation speed and hoe operation angle (not shown) are also parallel to each other. The results for hoe operation angles of 30^0 and 45^0 were not significantly different. **Figure 14** indicates that the reduction in h can be predicted by an equation of the form:

$h_r = kt^n$

where

h_r = reduction in h (mm)

t = operation time (h)

k and n = constants determinable experimentally or by regression analysis

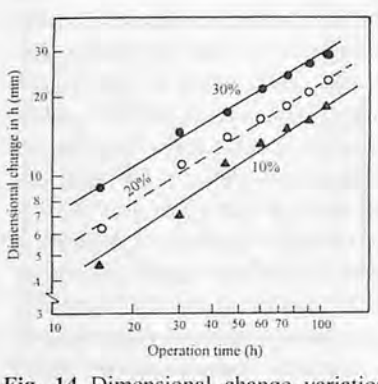

Fig. 14 Dimensional change variation with operation time (log-log sheet).

A typical variation of absolute mass with the operation time is shown in **Figure 15** for different soil moisture content levels. The absolute mass decreased almost linearly with the operation time for all soil MC level with the reduction being highest for 30% MC level and lowest for 10% MC level. Here again similar patterns were obtained for variable operation speed and variable hoe operation angle. The highest loss occurred at 8 km/h and the lowest at 2 km/h for variable operation speed and the highest loss occurred at 60^0 hoe operation angle for variable hoe operation angle. The relations were non-linear. Again the difference between hoe operation angles of 30^0 and 45^0 were not very substantial. Similar results have been obtained for cultivator shares operating at different soil MC levels (without variation in operation speed and share angle) in some Australian soils (Ferguson, Fielke and Riley, 1998).

The effect of gravel content on wear is shown in **Figure 16**: the higher the size of the aggregates in the soil the higher the wear. The stone and gravel content of the soil is one of the most important factors influencing the wear of tillage tools (Yu and Bhole, 1990) and this has been found to be the case in the present study. The effect of abrasive particle size on the wear of tillage tools is complicated by the fact that there is a large range of particle size present in soils (Ferguson, Fielke and Riley, 1998). These particles impart both abrasive and erosive wear to metals (Gahr, 1987 and Suh, 1988). Research in Australia has shown that the wear rate increased with the gravel content of the soil up to 20% gravel, at which point a higher percentage of gravel did not further increase the wear rate. Another research result agreed with this up to 10% gravel, which was the highest percentage of gravel contained in the test sites used (Ferguson, Fielke and Riley, 1998). The reason given for this phenomenon was that the gravel was held rigidly by the hard setting soil matrix at gravel content levels lower than 20%, while at gravel content levels higher than 20% it was held less rigidly making wear rate to remain constant. The results obtained in the present study agree with this finding because the wear rate increased with the gravel content level up to 22% gravel after which further increase with gravel content did not affect the wear. Soils with high gravel percentage are, therefore, not recommended for tillage. Such soil may be used for zero till or no till farming.

Conclusion

The wear of the Ghanaian hand hoe has been studied successfully using the rotating laboratory soil bin equipment, varying soil MC, operation speed and hoe operation angle. It was found that wear, measured as weight and dimensional loss of hoe, increased with the increasing soil MC level, operation speed, hoe operation angle and operation time. Hence it is advisable to till the land at low soil moisture content and moderate speed with the hoe inclined at about 45^0 to the soil surface. Mathematical relationships have been found for wear for quick wear assessment. The gravel content level of the soil must be low to reduce wear and extend hoe life. Soils with high gravel content must be reserved for no zero farming.

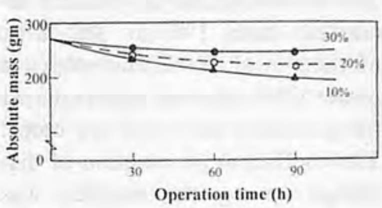

Fig. 15 Absolute mass variation with operation time.

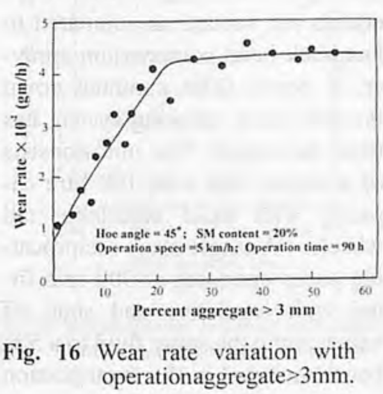

Fig. 16 Wear rate variation with operationaggregate>3mm.

REFERENCES:

Intermediate Technology Publishers. Tools for Agriculture - A Guide to Appropriate Equipment for Small Holder Farmers, 4th Edition, 1992

Baryeh E A Wear Characteristics of the Ghanaian Hand Hoe. Agriculture and Equipment International, 1997,49,(6), 197-200

Ferguson S A; Fielke J M; Riley T W Wear of Cultivator Shares in Abrasive South Australian Soils. Journal of Agricultural Engineering Research, 1998, 69, 99-105

Miller A E Wear in Tillage Tools. In: Wear Control Handbook (Editors: M D Peterson; W O Winer), ASME, New York, 1984, 987-998

Singh J; Shukla L N; Singh I Wear Characteristics of Reversible Shovels of Seed-cum-Fertilizer Drills. AMA, 1993, 24(4), 13-15

Foley A G; Chisolm C J; McLees V A Wear of Ceramic Protected Subsoilers. Tribology International, 1988, 21,(9), 97-103

Yu H; Bhole S D Development of a Prototype Abrasive Wear Tester for Tillage Tool Materials. Tribology International, 1990, 23(5), 309-316

Quick G R; Woods C R; Bartlett N R Effects of Speed and Other Parameters on Lineal Share Wear. Agricultural Engineering Australia, 1979, 8(2), 109-117

Gahr A G Microstructure and Wear of Metals. Elsevier Science Publishing Co, 1987

Suh, N.P. (1988): 'Tribophysics'. Prentice-Hall, Inc., Englewood Cliffs, New Jersey

Schefler O; Allen C Abrasive Wear of Steels in South African Soils. Tribology International, 1988, 21(3), 127-135

Czichos H Tribology - A systems Approach to the Science and Technology of Friction, Lubrication and Wear. Elsevier Scientific Publishing Co, 1978 ■■

Power Tiller-based Boom Sprayer

by
Dr. K. Kathirvel
Assistant Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University,
Coimbatore
India

Dr. T. V. Job
Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University,
Coimbatore
India

Dr. R.Manian
Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University,
Coimbatore
India

Abstract

In the dynamic and fast changing agricultural scenario in India, particularly diversification in the cropping pattern and commercialization of agriculture, more efficient and sophisticated equipment are required by farmers. Power tillers are visualized as potential source of power for small and medium sized farms in India because of their easy maneuverability and compact size. Hence to increase the versatility of power tillers, a power tiller operated booms prayer was developed and evaluated for its performance and compared with power and manually operated knapsack sprayers.

Introduction

Chemical crop protection is the most important field operation and will become even more widespread with the demand for better yield to fulfill the need of food for the exponentially growing world population. On an average, about one-third of the potential agricultural production of the world is annually lost to pests. In India, crops worth 70,000 million Rs.are lost every year. Of this 52 per cent losses are caused by insects and diseases, 33 percent by weeds and 15 percent by rodents, birds and nematodes. Minimizing avoidable losses is one way of enhancing agricultural production. In the dynamic and fast changing agricultural scenario of the country, particularly diversification in the cropping pattern and commercialization of agriculture, more efficient and sophisticated equipment are required.

The power tillers can be used for agricultural operations, transport purposes and stationary application for operating irrigation pumps, threshers, etc, besides their suitability for wet land application. Despite the much increasing popularity of power tillers there has not been a significant increase in its use in India as compared to the tractors in India and their use in Asian countries. With the power tillers of 8-10 hp range, the power can be used for spraying insecticides or pesticides for field crops, especially in garden and dry land conditions effectively. It can be run on farm roads or wider bunds adjacent to crop field. The development and evaluation of a power tiller based boom sprayer is reported in this paper.

Review of Literature

Cannon (1979) developed a tractor mounted wide boom sprayer with an actual field capacity of 23.8 ha/hr. The swath width of the sprayer was 24.4 m to cover 24 rows spaced at 1.016 m apart. Sukla et al. (1987) developed a wide swath tractor mounted sprayer for cotton crop. The spray boom consisted of 13 triple action nozzles with a spacing of 750 mm and two spray guns. The swath width was 12 m with a coverage of 1.2 ha/hr. The average nozzle discharge varied from 0.458 to 0.820 lit/min, as the pressure increased from 196 to 392 kPa. Mathew et al. (1992) developed a power tiller operated boom sprayer for groundnut and other row crops. The coefficient of variation of discharge among the nozzles was within 2 per cent for the pressure range of 294 to 392 kPa. It resulted in 29 per cent savings in cost of operation per hectare as compared to knapsack hand compression sprayer. A power tiller mounted down the row boom spraying system has been developed. The unit consists of a trailed tank with 100 litre capacity with tread adjustable tail wheels. A single stage reciprocating pump operating at 900 rpm fitted with regulators and shut off valve, pump the spray fluid to a 5 m boom mounted in the front portion

Fig. 1 Mounting of sprayer system on carrier.

Fig. 2 Sprayer in action.

of the power tiller. The boom carried 8 nozzles adjustable for spraying of different row crops. The boom's height also is adjustable from 25 to 60 cm. At an operating speed of 1.5 kmph, the application rate is 600 litres per hectare. The field capacity of the sprayer was 1 ha per hour. It was suitable for spraying row crops like cotton, maize, groundnut etc. The limiting factor for the use of this sprayer was that the spacing between the row-to-row and plant-to-plant should be such that the power tiller can be easily manoeuvred (Anon 1996).

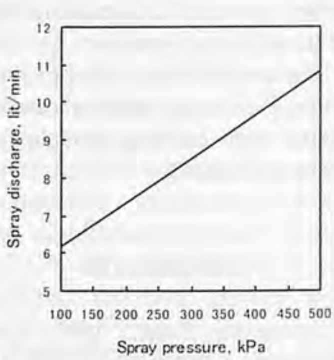

Fig. 3 Relationship between pressure and discharge rate of boom sprayer.

Methods and Materials

The power tiller operated boom sprayer unit consists of a 40 × 25 mm reciprocating pump placed in the centre portion of the power tiller above the tool box. It is fitted to the power tiller with a help of a frame and secured rigidly. The power to drive the pump is taken from the clutch pulley of the power tiller through V-belt transmission. A tension pulley is fitted to ensure proper tension of the belt. A 25 mm heavy duty alkathene suction hose carries the spray chemical from the chemical tank kept in the power tiller trailer to the inlet of the pump (**Fig. 1**). From the pump outlet the spray fluid is taken to the spray boom by means of 37 mm G.I. pipe. The delivery line from the outlet of the pump is divided into two lines by means of a two way cock to each of the two aluminium sections. A regulator valve with a bypass line to the tank is also provided in the delivery line to control the discharge rate of chemical and excess pressure. The spray boom is made of 50 × 25 mm aluminum hollow sections of 8 m length and it is fitted with 16 low volume hollow cone nozzles by means of G.I. clamp fittings. The nozzles are spaced at 450 mm. The spray boom assembly is carried by 2 persons with the support of "Belly rest" and "Neck belt" provisions (**Fig. 2**). The cost of the unit is Rs.10,000. The following parameters were measured in the laboratory prior to the field evaluation of the boom sprayer. The discharge rate of each nozzle was measured for the pressure range of 144.8 to 434.6 kpa. The spray liquid was collected in a measuring jar and the total discharge rate was determined by adding the individual nozzle discharge. The spray distribution pattern of the boom sprayer was observed using a patternator. The uniformity coefficient was calculated by using the volume of spray fluid collected in each tube of the patternator at different nozzle heights and spray pressures. The uniformity coefficient of droplet size was determined by measuring the volume median diameter (VMD) and mass median meter (MMD). The unit was evaluated for its performance in spraying of chemical for cotton crop and compared with power and manual knapsack sprayers.

Results and Discussion

The data observed during the laboratory tests are shown in **Table 1.**

The pressure versus discharge curve is presented in **Fig.3**. It is observed that the increase in pressure increased the discharge rate of the sprayer. The increase in discharge rate was 50 per cent for three-fold increase of pressure. The uniformity coefficient of droplet size reduced with an increase in pressure of spray fluid. The highest value was observed at 434.6 kPa pressure. But the uniformity coefficient of spray distribution at different nozzle heights increased with an increase in pressure and the maximum value was obtained at 434.6 kpa pressure. A similar trend was observed for the uniformity coefficient of spray distribution. The boom sprayer was evaluated for its performance for spraying cotton crop and compared with power and

Table 1. Performance Data of Boom Sprayer in Laboratory

Nozzle pressure, kPa	Discharge rate, lit/min	Uniformity coefficient of droplet size (%)	Uniformity coefficient of spray distribution (%)
144.8	6.62	1.28	39.6 to 541.2
193.1	7.20	1.25	42.8 to 55.7
241.4	7.82	1.22	44.7 to 63.3
289.7	8.45	1.16	57.9 to 73.2
337.6	8.95	1.14	54.4 to 74.6
434.6	10.01	1.11	56.8 to 78.5

Table 2. Abstract of Cost Appraisal of Boom Sprayer

Method of spray	Cost of operation (Rs/ha)	Time required hrs/ha	Percent savings	
			Cost	Time
Boom sprayer	60.66	0.89	-	-
Power operated knapsack sprayer	81.50	3.03	20.84	70.62
Manually operated knapsack sprayer	118.30	7.25	48.30	37.70

manually operated knapsack sprayers. The performance values observed during the field evaluation are as follows: speed of operation, 1.4 kmph; width of boom, 8 m; time required to spray one ha, 0.89 hrs; actual time taken to spray one ha, 1.45 hrs; and field efficiency, 61.38 per cent.

The abstract of cost appraisal of boom sprayer is shown in **Table 2**.

It is observed that spraying with boom sprayer results in 20.84 and 48.30 per cent savings in cost and 70.62 and 37.7 per cent savings in time when compared to power and manually operated knapsack sprayers, respectively.

Conclusion

The salient features of the unit include are; light in weight and easy handling; suitable for spraying in row crops; an area of 5 ha can be sprayed in one day; and results in 20.84 and 70.63 per cent savings in cost and 48.30 and 37.7 per cent savings in time when compared with power and manually operated knapsack sprayer, respectively.

REFERENCES

Cannon, M.D., 1979. Development of a wide boom field sprayer. *Trans. of ASAE*, 22(5): 997-999.

Sukla, L.N., N.S.Sandhar, Surender Singh and Joginder Singh, 1987. Development and evaluation of wide swatch tractor mounted sprayer for cotton crop. *Agric.Mech. in Asia, Africa and Latin America, 18(2): 33-36.*

Mathew, V.J., S.K.Dash, D.K. Dash and S.C.Pradhan, 1992. Development and testing of a power tiller operated boom sprayer. *Agric.Mech. in Asia, Africa and Latin America*, 23(4):. 25-27.

Anonymous. 1996. Annual report of All India Co - ordinated Research Project on Power tillers, Coimbatore centre, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore. ■■

(Continued from page 10)

A Twin-Purpose, Light Weight New Iron Plough

Field Evaluation of Ploughs

The ploughs were tested at different farmer's field in this region. The test results are presented in **Table 1**. The test results reveal that the new iron plough with country plough like plough bottom, on average, covered 0.44 to 0.48 ha per day of eight hours for dry ploughing and 0.40 to 0.44 ha for wetland puddling with mould board plough like plough bottom.

The existing wooden country plough on average, covered 0.35 to 0.40 ha during dry ploughing and the iron mould bound plough covered about 0.30 to 0.32 ha during wet puddling in a day of eight hours.

The newly developed twin purpose light weight iron plough required 36 and 31 kg of draft for dry ploughing and wet puddling whereas existing ploughs required 46 and 36 kg for dry ploughing and wet puddling, respectively.

The new plough covered 20 and 30 per cent more area on dry ploughing and wet puddling as compared to the country plough and Melur plough, respectively. In the newly developed plough, the pole shaft may require change once in 5 years and share as and when it is worn out. The expected life of the new plough is about 15 years whereas in the case of country plough it is 1 to 1.1/2 years and Melur plough 4 to 5 years.

The details of cost, draft, saving in time, coverage and per cent increase over existing ploughs are shown in **Table 1.**

REFERENCE

Gyanendra Singh, 1997. Constraints to Mechanisation. In: The Hindu Survey of Indian Agriculture. p.173-179. ■■

Selection of Equilibrium Moisture Content Equations for Some Fruits and Vegetables

by

Y. Soysal
Research Assistant
Department of Agricultural Machinery,
Faculty of Agriculture,
University of Çukurova,
01330 Balcal/Adana
Turkey

S. Öztekin
Associate Professor
Department of Agricultural Machinery,
Faculty of Agriculture,
University of Çukurova,
01330 Balcal/Adana
Turkey

Abstract

In this research, most commonly used EMC/ERH equations are compared based on their ability to fit the published sorption data to determine the best fitted equation for selected fruits and vegetables. Non linear regression technique is used to fit data sub-set. In order to compare the performance of the EMC/ERH equations, three statistical error parameters are used. The best-fitted equations provide a sound basis for future work on drying and storage of some fruit and vegetables are given.

Introduction

It is important to determine the equilibrium moisture content of agricultural crops for drying, storing, mixing and packaging due to the fact that all agricultural crops are generally hygroscopic. The moisture content (MC) of a wet material in equilibrium with air of given humidity and temperature is termed the equilibrium moisture content (EMC). All agricultural crops have different EMCs at similar conditions because they have different physical and chemical structures. A plot of EMC at a given temperature versus the dry-basis MC of the material is so-called sorption isotherm. An isotherm obtained by the exposing wet material to air of increasing humidity is termed the adsorption isotherm. That obtained by exposing the material to air of decreasing humidity is known as the desorption isotherm (Baker, 1997).

Several researchers have studied the relationships between the equilibrium moisture content and equilibrium relative humidity (EMC/ERH) to describe the sorption process mathematically. They developed more than 200 EMC/ERH equations that have appeared in the literature[9]. However, it is noted that no single equation has the ability to describe the EMC/ERH relationships for various crops over a broad range of the relative humidity and temperature accurately. These equations are generally used to describe the EMC/ERH relationships for cereal grain and food material.

Iglesias and Chirife (1982) determined the best fitted EMC/ERH equation using the adsorption data for various agricultural crops. Cenkowski et all. (1982) developed a method for calculating the latent heat of vaporisation for selected foods and crops using the EMC/ERH equations.

Sun (1998) studied on determining the best fitted EMC/ERH equation for grain and oilseed using the published sorption data. In his research, it is quoted that the Modified Chung-Pfost equation, Modified Oswin equation, Strohman-Yoerger equation and Modified Halsey equation were identified as the most appropriate equations for describing the EMC/ERH sorption isotherms for wheat, shelled corn, rice and rapeseed, respectively. In addition, the authors concluded that the Modified Henderson equation was found among the least successful equations.

Ayranc et al., (1990) studied on determining the moisture sorption isotherms of dried apricot, fig and raisin at 20 and 36°C. They compared the Iglesias and Chirife, Halsey, BET and GAB equations based on their ability to fit the experimental data. In this research the GAB model was found to be the best fitted equation for dried apricot and raisin isotherms at 20-36°C and at 20°C, respectively. Additionally, the Halsey equation was found as the best for isotherms of dried fig at 36°C while the Iglesias and Chirife equation was best for the isotherm of dried fig at 20°C.

Considerable quantities of fruits and vegetables produced in the world are consumed as dry products. These crops generally contain

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high MC. Therefore, they should be dried and stored in suitable conditions to preserve the crop quality for long periods. In this respect EMC/ERH relationships must be known to determine the suitable storage condition for a particular crop.

Additionally, EMC/ERH relationships can be used to determine the latent heat of vaporisation of a particular crop. The latent heat of vaporisation may be used to determine the heat energy requirement for drying. Therefore, the present study was conducted to determine the best fitted EMC/ERH equations for some fruits and vegetables. Most commonly used EMC/ERH equations for grains are used to fit the published data sub-set.

Materials and Methods

In present research the following most commonly used EMC/ERH equations were used to determine the best fitted equation for selected fruits (pineapple, avocado, banana and grapefruit) and vegetables (celery, aubergine, leek and lentil) using the Modified Oswin equation (MOSE) (Oswin, 1946);

$$ERH = \frac{\left(EMC/B_0\right)^{\frac{1}{B_1}}}{1+\left(EMC/B_0\right)^{\frac{1}{B_1}}} \qquad (1)$$

Halsey equation (HAE) (Halsey, 1948);

$$ERH = EXP\frac{-B_0}{EMC^{B_1}} \qquad (2)$$

Henderson equation (HE) (Henderson, 1952);

$$ERH = 1 - EXP\left(-B_0 EMC\right)^{B_1} \qquad (3)$$

Where;

ERH– equilibrium relative humidity (decimal),

EMC– equilibrium moisture content (% d.b.),

B_0 and B_1 _ coefficients (-)

Published adsorption data were used in statistical evaluation process (Wolf et al., 1973). Non-linear regression technique in SAS was used to fit data sub-set (SAS, 1996). The regression results include the best fitted coefficients for the equations, residual sum of squares (RSS), standard error of estimate (SEE) and R squared value (R^2).

Results and Discussion

The data used in the study were fitted according to a non-linear regression process and the regression results include the best fitted coefficients for the equations, residual sum of squares (RSS), standard error of estimate (SEE) and R squared value (R^2). **Table 1** gives the best fitted coefficients of the compared equations, RSS, SEE and R^2 values. The selection of the best-fitted equation was based on the three-error parameters mentioned above. As shown in **Table 1**, Modified Oswin equation can be used to describe the EMC/ERH relationships for the pineapple and lentil over a broad range of relative humidity and temperature, accurately. There is no single equation to describe the EMC/ERH relationships for the avocado, grapefruit, banana, celery, aubergine and leek, accurately. However, the Modified Oswin equation can be used to describe the EMC/ERH relationships of all selected fruits and vegetables over a broad range of relative humidity and temperature. The Halsey equation can also be used to describe the EMC/ERH relationships of the avocado, grapefruit, banana, celery, aubergine and leek over a broad range of the relative humidity and temperature. The Henderson equation can only be used for pineapple.

Table 2 gives the number of fits producing minimum error values for each equation. The Modified Oswin equation generally produces much more reliable results for the temperature range from 5 to 45°C compared to two other equations. The Halsey equation gives much more reliable results for the 60°C temperature level. The results obtained in the study suggested to use the Modified Oswin equation for 5 to 45°C temperature ranges and the Halsey equation for the 60°C temperature level to obtain the maximum accuracy, as the Henderson equation was found to be the least successful equation to fit the experimental data.

Conclusions

It is confirmed that the non-linear regression techniques can be used to describe the EMC/ERH relationships for fruits and vegetables. The Modified Oswin equation has the ability to fit adequate experimental data and can be used to describe the EMC/ERH relationships of all the selected fruits and vegetables over a broad range of relative humidity and temperature. Additionally, the Modified Oswin equation can be used to describe the EMC/ERH relationships for the pineapple and lentil over a broad range of accurate relative humidity and temperature.

The Halsey equation produces much more errors compared to the Modified Oswin equation. However, it can be used to describe the EMC/ERH relationships of avocado, grapefruit, banana, celery, aubergine and leek over a broad range of relative humidity and temperature.

The Henderson equation is among the least successful equations for selected fruits and vegetables. It can only be used for pineapple.

The Modified Oswin equation and Halsey equation generally produce much more reliable results for the 5 to 45°C and 60°C, respectively. Therefore, Modified Oswin equation is suggested for use in the 5-

45ºC temperature range and the Halsey equation for the 60ºC temperature level to obtain maximum accuracy.

The techniques provide a sound basis for future work on drying and storage, may be useful for examining EMC/ERH data for other fruits, vegetables, food, grains, medicinal and aromatic plants.

REFERENCES

Baker, C.G.J., 1997. Industrial Drying of Foods. Blackie Academic and Professional, an imprint of Chapman & Hall, 2-6 Boundary Row, London SE 1 (NH, UK. P. 309.

Cenkowski, S., D.S. Jayas and D. Hao, 1992. Latent Heat of Vaporization for Selected Foods and Crops. Can. Agric. Eng. Vol: 34, No: 3, pp. 281-286.

Ayranc, E., Ayranc, G., and Do antan, Z., 1990. Moisture Sorption isotherm of Dried Apricot, Fig and Raisin at 20ºC and 36ºC. J. of Food Sci. Vol. 55, No. 6, pp. 1591-1593.

Halsey, G., 1948. Physical Adsorbtion in Non-Uniform Surfaces. J.

Table 1. The Best Fitted Coefficients, RSS, SEE and R2 Values for Adsorptive Isotherm Equations

Crop	Temp. (ºC)	Equation	B_0	B_1	RSS	SEE	R^2
Pineapple	5	MOSE	12.8936254600	0.9583784100	0.00356061900	0.0219	0.9937
		HAE	3.5979999940	0.6633250310	0.01479033750	0.0433	0.9737
		HE	0.3711542925	0.1299877068	0.01539944888	0.0215	0.9726
	25	MOSE	12.8936254600	0.9583784100	0.00356061900	0.0219	0.9937
		HAE	3.5979999940	0.6633250310	0.01479033750	0.0433	0.9737
		HE	0.3711542925	0.1299877068	0.01539944888	0.0215	0.9726
	45	MOSE	10.2212744900	0.9798058500	0.00096960880	0.0197	0.9983
		HAE	3.2831216190	0.6584512570	0.01089229000	0.0372	0.9806
		HE	0.3406382326	0.1599723657	0.01937948090	0.0262	0.9655
	60	MOSE	11.4329027600	0.9688942100	0.00149187800	0.0095	0.9973
		HAE	2.9905317680	0.6505705980	0.00890111720	0.0340	0.9842
		HE	0.3200000000	0.1900000000	0.02280679530	0.0302	0.9594
Avocado	25	MOSE	6.6203211810	0.5688948380	0.00171232510	0.0149	0.9970
		HAE	5.7608769190	1.1486564100	0.00126155260	0.0129	0.9978
		HE	0.8200000000	0.1200000000	0.02497670020	0.0283	0.9556
	45	MOSE	5.2760761600	0.7009567940	0.00050013810	0.0080	0.9991
		HAE	3.0898606130	0.9287678450	0.00299148670	0.0195	0.9947
		HE	1.0300000000	0.1200000000	0.00681345210	0.0284	0.9879
	60	MOSE	2.7302129910	0.8102786280	0.02192433960	0.0540	0.9610
		HAE	1.5177383690	0.8400376590	0.00708509520	0.0310	0.9874
		HE	1.1000073780	0.2200762610	0.05031923710	0.0740	0.9105
Banana	25	MOSE	10.8211623700	0.9138247700	0.0038774051	0.0227	0.9931
		HAE	3.6485352110	0.7218225450	0.0007865318	0.0105	0.9986
		HE	0.8400415881	0.0700047424	0.0309843707	0.0498	0.9449
	45	MOSE	8.5302979580	0.9258161530	0.0242226109	0.0574	0.9569
		HAE	3.2801373590	0.7561615680	0.0094267868	0.0362	0.9832
		HE	0.9700000000	0.0800000000	0.0720104690	0.0796	0.8719
	60	MOSE	7.1552703200	0.9549861770	0.0444645199	0.0782	0.9209
		HAE	2.8260840430	0.7534432150	0.0249725652	0.0589	0.9556
		HE	1.3802732560	0.0700278650	0.1018311561	0.0942	0.8189
Grapefruit	5	MOSE	11.0350858400	1.1346771800	0.0050400888	0.0267	0.9910
		HAE	2.4417717170	0.5471905530	0.0142096700	0.0442	0.9747
		HE	0.4001419112	0.1309940894	0.0459690873	0.0404	0.9182
	25	MOSE	11.0350858400	1.1346771800	0.0050400888	0.0267	0.9910
		HAE	2.4417717170	0.5471905530	0.0142096700	0.0442	0.9747
		HE	0.4001419112	0.1309940894	0.0459690873	0.0404	0.9182
	45	MOSE	9.3039657990	1.0558996560	0.0016993443	0.0154	0.9970
		HAE	2.4823498260	0.5947349010	0.0103770085	0.0372	0.9815
		HE	0.3100000000	0.2110000000	0.0352359751	0.0353	0.9373
	60	MOSE	4.7477228932	0.9933796460	0.0134860655	0.0421	0.9760
		HAE	0.0027460898	1.9012882510	0.0027460898	0.0194	0.9951
		HE	1.2000206340	0.1210040820	0.0637913358	0.0628	0.8865
Celery	5	MOSE	12.6940067100	0.6079126100	0.0003761327	0.0069	0.9993
		HAE	0.3099938401	0.1670012048	0.0141545102	0.0208	0.9940
		HE	9.8974144750	1.0664801700	0.0033494932	0.0203	0.9748
	25	MOSE	11.8562080600	0.6740641000	0.0027285552	0.0197	0.9951
		HAE	0.4300000000	0.1270000000	0.0080354752	0.0315	0.9872
		HE	6.8036679110	0.9447203520	0.0072135558	0.0269	0.9857
	45	MOSE	8.6460098510	0.7781230590	0.0076228612	0.0319	0.9864
		HAE	0.2100000000	0.3530000000	0.0224817096	0.0096	0.9988
		HE	4.1910556120	0.8621969680	0.0006554487	0.0541	0.9600
	60	MOSE	7.7042977320	0.7370276850	0.0131335334	0.0426	0.9766
		HAE	0.4999903698	0.1670239771	0.0330132716	0.0197	0.9969
		HE	4.3881800890	0.9244531630	0.0017445677	0.0661	0.9413

.....Continued

Table 1. Continuation

Crop	Temp. (°C)	Equation	B_0	B_1	RSS	SEE	R^2
Aubergine	5	MOSE	17.6487299400	0.6088101300	0.00223801120	0.0177	0.9960
		HAE	13.0353608400	1.0403257200	0.01053144830	0.0374	0.9813
		HE	0.5400000000	0.0700000000	0.01212905930	0.0055	0.9784
	25	MOSE	13.6883746100	0.6279712900	0.00122500750	0.0126	0.9978
		HAE	10.1680148100	1.0462292000	0.00186247730	0.0153	0.9967
		HE	0.5299538506	0.0899980912	0.01357241250	0.0288	0.9759
	45	MOSE	7.8324093260	0.9039932450	0.00320287320	0.0213	0.9943
		HAE	2.9382086590	0.7237208890	0.00664944250	0.0292	0.9882
		HE	1.0300000000	0.0800000000	0.02550989550	0.0437	0.9546
	60	MOSE	3.7254207480	1.0098762040	0.00978909040	0.0342	0.9826
		HAE	1.5800847580	0.6619218300	0.00245011930	0.0311	0.9956
		HE	0.7404533790	0.2500044628	0.05596588360	0.0458	0.9005
Leek	5	MOSE	4.0235518290	0.3884942220	0.00075057490	0.0103	0.9987
		HAE	6.6436479260	1.6599128670	0.00742284510	0.0308	0.9868
		HE	0.5000000000	0.3260000000	0.09286737440	0.0179	0.8348
	25	MOSE	3.4176573600	0.4142167370	0.00218714740	0.0171	0.9961
		HAE	4.7523705480	1.6076972300	0.00180975180	0.0146	0.9968
		HE	0.7700000000	0.2450000000	0.08166029570	0.0281	0.8548
	60	MOSE	2.0825372700	0.5915853840	0.00921652140	0.0352	0.9836
		HAE	1.5400370850	1.1501142980	0.00410629070	0.0228	0.9927
		HE	1.0700000000	0.2880000000	0.03080314440	0.0575	0.9452
Lentil	5	MOSE	13.0480150000	0.3930738600	0.0012174853	0.0127	0.9978
		HAE	0.3600000000	0.1410000000	0.0848635458	0.0339	0.9828
		HE	47.3909602800	1.6636732800	0.0096428000	0.0292	0.8491
	25	MOSE	12.2262672900	0.4001612300	0.0001084830	0.0038	0.9998
		HAE	0.2999424760	0.1789973324	0.0825008037	0.0269	0.9889
		HE	40.3402059800	1.6422478800	0.0062466461	0.0232	0.8533
	45	MOSE	9.2073850620	0.5086563420	0.0008387612	0.0108	0.9985
		HAE	0.3800000000	0.1880000000	0.0361063783	0.0221	0.9922
		HE	12.0517852400	1.3074769300	0.0043721449	0.0252	0.9358

Table 2. Frequency of Fits Producing Minimum Error for Each Equation

Crop	MOSE				HAE				HE			
	5°C	25°C	45°C	60°C	5°C	25°C	45°C	60°C	5°C	25°C	45°C	60°C
Pineapple	✓	✓	✓	✓	*	*	*	*	*	*	*	*
Avocado		*	✓	*		✓	*	✓		*	*	
Banana		*	*			✓	✓	✓				
Grapefruit	✓	✓	✓	*	*	*	*	✓				
Celery	✓	✓	*	*	*	*	✓	✓	*	*	*	
Aubergine	✓	✓	✓	*	*	*	*	✓	*	*	*	
Leek	✓	*		*	*	✓		✓				
Lentil	✓	✓	✓		*	*	*					

Legend: ✓ = Best fitted equation producing minimum error and * = Reasonable equation.

of Chem. Phys. Vol: 16, pp. 931-937.

Henderson, S.M., 1952. A Basic Concept of Equilibrium Moisture. Agricultural Engineering. Vol: 33 pp. 29-32.

Iglesias, H.A., and J. Chirife., 1982. Handbook of Food Isotherms: Water Sorption Parameters for Food and Food Components. Toronto, ON: Academic Press.

Oswin, C.R., 1946. The kinetics of Package Life. III. Isotherm. J. of the Soc. of Chem. Ind. Vol: 65, pp. 419-421.

SAS, 1996. SAS Institute Inc. SAS User's Guide: Statistics, 1982 Edition. Cary, NC. P. 584.

Sun, Da-Wen and Woods, J.L., 1994. The Selection of Sorption Isotherm Equations for Wheat Based on the Fitting of Available Data. J. of Stored Product Research. Vol: 30 (1), pp. 27-43.

Sun, Da-Wen, 1998. Selection of EMC/ERH Isotherm Equations for Drying and Storage of Grain and Oilseed. 13th Int. Congress on Agric. Eng. Proceedings, Rabat 2-6 February 1998. Vol: 6, pp. 331-336.

Wolf, W., Spiess, W.E.L. and Jung, G., 1973. Die Wasserdampfsorptionsisothermen einiger, in der Literatur bislang wenig berücksichtigter Lebens-mittel. Lebensm.-Wiss. u. Technol. Vol: 6, No: 3.

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Effects of Soil Strength on Root Growth of Rice Crop for Different Dryland Tillage Methods

by

Md. Ashraful Haque
Assistant Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University,
Mymensingh-2202
Bangladesh

Murshed Alam
Associate Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University,
Mymensingh-2202
Bangladesh

R.I. Sarker
Professor
Dept. of Farm Power and Machinery
Bangladesh Agricultural University,
Mymensingh-2202
Bangladesh

Abstract

The present study summarizes the effects of soil strength on root growth of rice plants in different plots ploughed by bullock-operated country plough, power tiller-mounted rotary plough and tractor mounted mould board plough under dry soil condition. The influence of soil strength on root growth of rice variety BR-8 in silty loam soil was studied. A soil penetrometer was used to observe and measure the soil strength. A glass box was used to measure the root growth. The root growth was measured at 7-day interval for a period of 64 days at different soil strength. The relationship between soil strength (affected by tillage) and plant root growth was expressed by a linear equation. It was observed that the root growth was not significantly affected by the different tillage methods and that higher soil strength impeded the root growth. Statistical F-tests also show that there was no significant difference between tillage methods on soil strength and root growth of the rice crop.

Introduction

Investigations on the root systems of crops growing in the field are very difficult because of our inadequate knowledge of the interaction between the soil, the roots and aerial parts of the plant. Equally important is the interaction between neighbouring root systems which is also not well understood. The rate of root growth depends on the temperature, water and air supply in the soil, on the amount of carbohydrates and on the competition with other roots. Roots will grow in soils in which there are adequate number of channels large enough for the roots to penetrate (Russel, 1971). Tillage tools are used to improve soil structure and porosity and to disrupt or modify compacted soil layers that impede water movement, gaseous diffusion and root growth. Thus, tillage manipulates the soil by mechanical forces to prepare seed beds and aerate the soil for root growth in crop production (Charles, 1985).

Bangladesh is one of the 111 rice producing countries of the world. It has 13.70 million ha of cultivable land of which 10.18 million ha are planted to rice (BBS, 1995). Dryland tillage is adopted in the country mainly in the winter and part of summer seasons (November to March). It is, therefore, important to study the effect of dryland tillage on soil strength and its subsequent influence on root growth of the rice crop under Bangladesh soil and climatic conditions. Many of the studies investigating rice root growth have been restricted to one or two growth stages (Beyrouty et al., 1988). This present research aimed to arrive at a complete understanding of dryland tillage effects on rice root growth starting at identifying all variables affecting the overall production of rice per unit area of land.

Objectives

The main objective of the study was to compare the root growth of rice crop in the field under three different land preparation methods such as bullock operated country plough followed by laddering, power tiller operated rotary plough, and a tractor-mounted mould board plough followed by harrowing with a disc harrow as practiced in Bangladesh.

The secondary objectives were: (i) to find out the relationship between soil strength vs. root growth; and (ii) to compare seed bed soil strength under three tillage methods for land preparation.

Materials and Methods

Experiments were conducted at the Bangladesh Agricultural University Farm. An area of 0.21 ha was selected and divided into 3 plots (P_1, P_2, and P_3) for dryland tillage. Three different tillage methods, 1, 2, and 3, as described below, were adopted for the experiment in the plots P_1, P_2 and P_3, respectively.

Tillage method 1- A pair of bullocks with an estimated power of 0.46 kW was engaged to operate the country plough and ladder in tillage operation at plot- P_1. The numbers of passes for tillage operation were 5 followed by one laddering operation.

Tillage method 2- A power tiller (2-wheel tractor) of 7.5 kW nominal rating (Yanmar Model:YZC ES 105C, made in Japan), equipped with a rotary plough, was used for tillage operation at plot- P_2. The number of passes for tillage operation were 3.

Tillage method 3- Tillage operation at plot- P_3 was accomplished with a 4-wheel farm tractor "International 434" of 30 kW nominal rating equipped with a 3-bottom, 20-cm mould board plough and an offset disk harrow with 17 disks arranged in two gangs. The land was prepared by one ploughing followed by two harrowing operations. The soil belonged to silty loam type at all the plots. The soil physical and mineralogical properties of the experimental farm are shown in **Table 1**.

The entire plot received an application of 14 kg, 12.6 kg and 8.4 kg of N_2, P_2O_5 and K_2O, respectively. Half of the N_2 was applied during tillage, 25% N2 at 30 and 50 days after sowing (BRRI, 1995). Each three tillage treatments by the three power sources with three replications were conducted in the plots. Tilling depths were maintained at 11-15 cm. Before sowing the average soil strength and bulk density were 0.32 MPa and 1.35 gm/cc, respectively. At this stage BR-8 paddy seeds were sown and within 4 days germination occurred. Sowing was completed in the months of April-May each year. Soil strength was measured as soil penetration resistance with a Reviakin Penetrometer at seven days intervals for a period of 64 days (before flowering) to correlate with root growth.

In order to measure the root growth under controlled condition, a rectangular glassbox of 40 × 30 cm size was set at a depth of 40 cm around each plant. Three rice plants were surrounded in each plots (diagonally) to conduct the experiment. Three sides of the box was packed up with tilled soil and one side was kept open in such a way that during recording data, the roots are not injured. Six readings were taken per plot for the three plants at the points 'A' and 'B' (**Fig. 1**) to measure soil strength at different times of plant growth. Corresponding temperature and rainfall data during root growth were collected from the Bangladesh Agricultural University Weather Yard. After every 7 days root growth, with respect to the corresponding soil strength, was recorded in the plots P_1, P_2 and P_3. The open surface of the glass box was graduated in centimeters for accurate measurement of root growth. Utmost care was taken to maintain natural condition for the growth of the rice plant.

The F-test was done for verifying the hypothesis that there was no significant differences in the three tillage methods on soil strength and root growth of the rice crop. The null hypothesis was set as follows:

There is no difference among the means of the three treatments.

i.e. H_0: $\mu_1 = \mu_2 = \mu_3$

Result and Discussion

Soil Strength vs. Root Growth in Plot P_1

The soil strength was recorded in plot P1 after 7 days of seed germination, amounting to 0.64 MPa. It increased linearly up to the value of 0.90 MPa then gradually decreased to a value of 0.57 MPa (**Fig. 2**). The variation of soil strength was not uniform during the 64 days of experiment. This occurred due to the variation in rainfall and soil moisture content (MC) which thereby affected the soil strength. The standard deviation of soil strength during root growth was 0.10 MPa.

The root growth was linear in the period of 64 days varying from 2.7 to 21.0 cm (**Fig. 2**). The standard deviation of root growth was 6.46 cm.

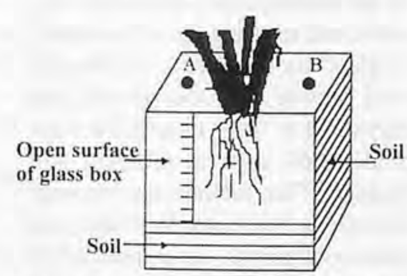

Fig. 1 Root measuring technique of rice seeding in field condition.

Table 1. Physical and Mineralogical Properties of Subject Soil

Soil property	Plots		
	P_1	P_2	P_3
Texture	Silty loam	Silty loam	Silty loam
Clay,%	10.00	8.00	10.00
Silt, %	72.00	68.00	64.00
Sand,%	18.00	24.00	26.00
Moisture content (d.b.),%	25.00	28.00	30.00
Initial bulk density, gm/cc	1.46	1.45	1.42
Initial soil strength, MPa	0.79	0.75	0.76

Fig. 1 Root measuring technique of rice seedlings in field condition.

It was observed from the experiment that the resistance to root growth was largely due to the variation in soil strength. The relation between soil strength (ST) and root growth (RG) in silty loam soil was expressed by the linear equation as:

$$RG = 35.76 - 32.16\,ST \quad (r = -0.51) \qquad (1)$$

where r = correlation co-efficient

The negative value of the slope indicated that the soil strength impeded the root penetration.

Soil Strength vs. Root Growth in Plot P_2

The soil strength in the plot P_2 increased linearly from 0.59 to 0.80 MPa for 16 days. The maximum value of soil strength was 0.84 MPa and then gradually decreased to 0.59 MPa. It was interesting to note that soil strength at the beginning and end of the experiment was identical after a period of 64 days. The minimum and maximum values of soil strength were in the range of 0.59 to 0.84 MPa (**Fig. 3**) during the experiment. Soil strength was not uniform during the field experiment. The standard deviation of soil strength was 0.09 MPa.

In plot P_2 the roots of the seedlings were initially 2.80 cm, on average but after 64 days of experiment the roots were as long as 22.50 cm (**Fig. 3**). The root growth was influenced by the variation of soil strength during the experiment. The magnitude of root growth variation was expressed by standard deviation which was 6.73 cm. The soil strength (ST) that affected the root growth (RG) in plot P_2 was shown by the following relation as:

$$RG = 37.34 - 35.85\,ST \quad (r = -0.49) \qquad (2)$$

Similar to the plot P_1, the negative value indicated that the soil strength impeded the root growth.

Soil Strength vs. Root Growth in Plot P_3

In the plot P_3, tillage effects on root growth of the rice crop were observed for tractor-tillage. Root growth rate as well as soil penetration resistance were recorded on weekly basis. The average temperature and rainfall in the research station varied in the range of 26 to 30 C and 0 to 37.5 mm, respectively, during the experiment. The initial soil strength was 0.68 MPa and increased linearly up to 0.95 MPa (the highest) within a period of 24 days. Then the soil strength decreased gradually by the days. The lowest value of soil strength was 0.57 MPa on the 56th day of experiment and after 64 days the soil strength again raised to a value of 0.59 MPa (**Fig. 4**). The ups-and-downs of soil strength was mainly due to the rainfall in the experimental station. The variation of soil strength was limited to 0.57 - 0.95 MPa and the standard deviation was 0.13 MPa.

Initially the root length was 3 cm in plot P_3 and then increased linearly up to 21.40 cm within 64 days of experiment. The root growth was not uniform throughout the experimental period. The phenomenon was due to the soil temperature, moisture content, rainfall and soil strength. The standard deviation of root growth of the rice crop was 6.37 cm. The relationship between soil strength (ST) and root growth (RG) was shown by linear regres-

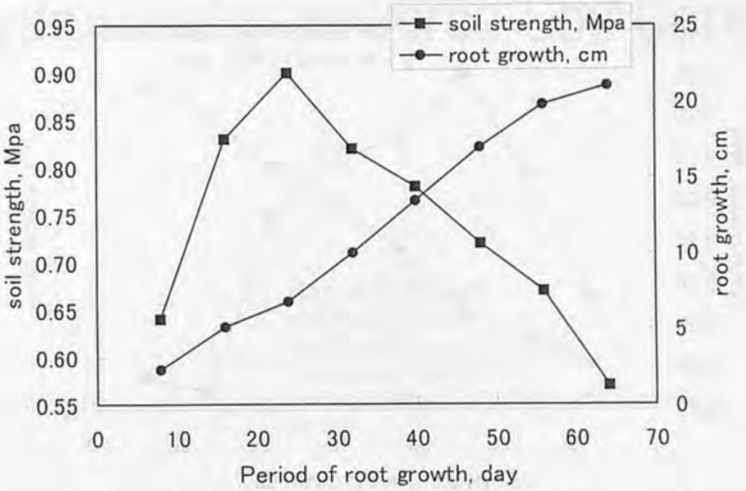

Fig. 2 Relationship of root growth and soil strength in dryland tillage by bullocks.

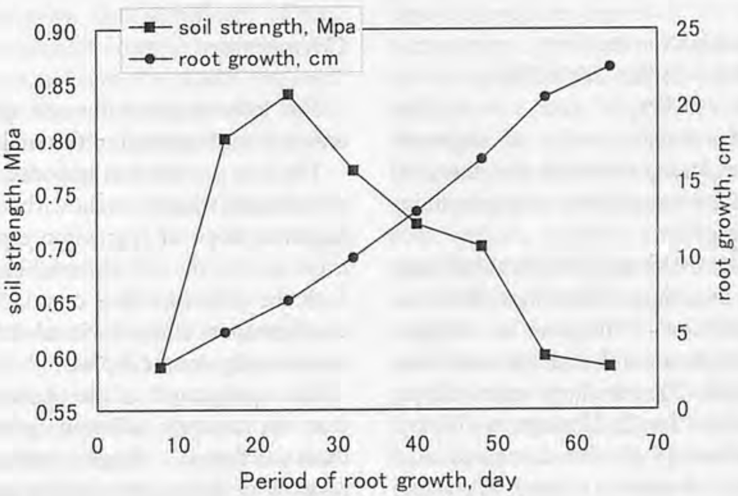

Fig. 3 Relationship of root growth and soil strength in dryland tillage by power tiller.

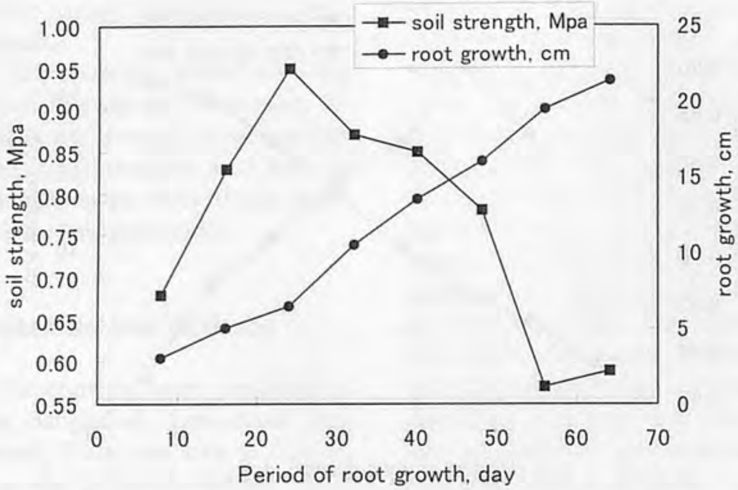

Fig. 4 Relationship of root growth and soil strength in dryland tillage by tractor.

sion equation as:

RG = 33.72 - 28.50 ST

(r = -0.57) (3)

The negative value of slope of the equation indicated that the soil strength impeded the root growth in the plot P_3.

The F-test was done for verifying the hypothesis that there was no significant difference in tillage methods on soil strength and root growth. The tabulated value of F at 5% level for (2, 21) degrees of freedom was 19.45. The calculated values of F were 0.61 and 0.004 for soil strength and root growth, respectively. Therefore, the hypothesis was accepted at 5% level. That is, the effect of tillage methods on soil strength and root growth was not significant.

Conclusion

The following conclusions were drawn from the result of the study:

The root growth was impeded by soil strength which was shown by the negative slope of regression equations as -32.16, -35.85 and -28.50 with the corresponding correlation coefficients of -0.51, -0.49 and -0.57, respectively, for the 3 plots.

The root growth of the rice crop was not severely affected by the three different tillage methods adopted in the experiment for land preparation. Rather, the soil strength influenced the root growth in shallow rooted plants.

Besides other parasitic factors like temperature, moisture and soil nutrients, the root growth was turned out to be a function of soil strength.

REFERENCES

Bangladesh Bureau of Statistics (BBS). 1995. Statistical Year Book of Bangladesh. Ministry of Planning, Government of Peoples' Republic of Bangladesh. pp. 628.

Beyrouty, C.A., Wills, B.R., Norman, R.J., Marvel, J.N. and Pillow, J.A. 1988. Root growth dynamics of rice cultivar grown at two locations. Agronomy Journal, American Soc. of Agron. Publication.

BRRI. 1995. Aadhunik Dhaner Chash. (Bengali Version) Published by Bangladesh Rice Research Institute, Gazipur-1701. pp. 60.

Charles, B.E. 1985. Plant root as tillage tools. International conference on soil dynamics, Proceedings vol. 3, Auburn, Alabama, USA. pp. 519-523.

Russel, E.W. 1977. Soil Conditions And Plant Growth. 10th Edt. The English Language Book Society and Longman. pp.849.

Saleque, U.M. 1990. System development for the reduction of energy requirement in tillage operation. Dept. of Farm Power and Machinery, Bangladesh Agricultural University, Mymensingh. Research Report: FPM No. 8.

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Description of a Hydraulically-powered Soil Core Sampler (HPSCS)

by
Nidal H. Abu-Hamdeh
Assistant Professor
Agricultural Engineering and
Technology Department
Jordan University of Science and Technology
P.O. Box 3030, Irbid, Jordan
E-mail: nidal@just.edu.jo

Hamid F. Al-Jalil
Associate Professor
Agricultural Engineering and
Technology Department
Jordan University of Science and Technology
Jordan

Abstract

The design of a hydraulically-powered soil core sampler used to collect undisturbed soil samples at different depths in the field is presented. The hydraulic actuation of the coring probe reduces the physical effort and time required by the operators. The device is constructed from a three-point hitch frame equipped with a gearbox, retractable legs, hydraulic cylinder and probe. The legs are driven from the tractor power takeoff shaft through a gearbox that can change the direction of rotation of worm gear shaft. The worm gears drive power screws that extend the legs to hold part of the tractor weight. The tractor auxiliary hydraulic power actuates the cylinder to push the probe into the soil. The device was tested in the field successively to collect soil samples for physical properties measurements.

The results from the field compaction study of the hydraulically-powered soil core sampler confirmed that the system could rapidly collect soil cores for measuring soil properties. Changes in soil physical properties caused by a KUBOTA M8030 tractor with 18.4 R30 tires at 100 kPa with a loaded 1500-kg seed drill mounted on the tractor were measured for soil samples obtained by the soil core sampler and by the manual sampling method. The bulk density and total porosity data from this field experiment show that significant effects were present down to a depth of 50 cm. In addition, the results obtained using the soil core sampler were close to those obtained by the manual sampling method

Introduction

Precise and rapid in-situ characterization of soil physical properties is a major constraint toward development and adoption of sustainable systems of soil surface management. Presently, the measurement of most soil physical properties is a time-consuming process. For this reason, much soil-related studies focus on changes in only one property such as bulk density, cone index or saturated hydraulic conductivity. A review by Soane et al. (1981) indicates the need to collect data as rapidly as possible to avoid variations in soil properties due to weather changes. Collection of data within the period of 1 or 2 days is suggested.

Farmers and agricultural researchers around the world are concerned about soil compaction. High-wheel loads from large tractors and machinery is suspected to be the major cause of such compaction. Other factors such as high soil moisture content (MC) during field operations, intensive tillage and the absence of grass incorporation is also believed to contribute to the compaction problem. Excessive soil compaction has long been recognized as a potential problem detrimental to crop production. Decreases in infiltration, hydraulic conductivity, seed germination, root growth, nutrient uptake, and crop yields are all symptoms of soil compaction. However, even for soils where many of these symptoms are apparent, the compaction process is not well understood. The lack of understanding is closely related to the deficiency in instrumentation and techniques for measuring soil compaction. Many of these compaction symptoms are related to changes in the soil's physical properties. Presently, the measurement of most soil physical properties is a time-consuming process. Compounding the problem of quantifying the properties is the large variations among soil samples and the disturbance of these samples. Many researchers identify the need to collect the data as rapidly as possible to avoid changes due to weather, etc. This indicates the need for a portable system to measure soil physical properties rapidly, accurately and with a minimal operator's effort. Morgan et al., (1993) describe a soil test vehicle on which instruments could be mounted for the measurement of bulk density, porosity, air permeability and cone penetration resistance. The system reduced the time and physical effort required to make the field measurements by the operators.

This paper shows the design of a hydraulically-powered soil core sampler (HPSCS) used to collect soil samples at different depths in the field (**Figure 1**). The soil samples will be used to measure physical properties (density, porosity, and permeability, strength, moisture content, etc.) of soil cores. The data obtained will be useful for the study of tillage effects and soil compaction on soil physical properties. Also, the data will be important to civil engineers in the construction field. A main benefit of the system is that it is expected to sample 10 core samples down to a depth of 50 cm within about 10 minutes or less.

Background

Compaction of soils has been a matter of increasing concern to farmers, agricultural research and civil engineers. Compaction of soils is seldom measured directly. The usual procedure is to determine the change in a parameter or set of parameters as a consequence of a compacting force. Compaction of agricultural soils results in increased soil bulk density (Blake, 1965; Mckibben, 1971; Wells and Burt, 1984; Ngunjiri and Siemens, 1993), and decreased porosity (Wood et al., 1993), hydraulic conductivity (Gupta et al., 1990; Wood et al., 1993) and air permeability (Freitag, 1971; Kunnemann and Wittmuss, 1976). In fact, many of the research used the measurement of such properties for the evaluation of soil compaction.

Soil bulk density is one of the most frequently used measures for compaction. Bulk density is found by determining the weight of dry soil sample that occupies a core of known volume. The core sampling method usually determines bulk density. In this method, an open ended metal cylinder is either pressed or hammered into the soil. The cylinder is then excavated and weighted together with the soil core after the latter has been trimmed flush with the ends of the cylinder. As the volume of the cylinder is known, the bulk density can be calculated by dividing the oven-dry weight of the core by its volume. This method has been widely used over several decades (Lutz, 1947; Jamison et al., 1950; Tessier and Steppuhn, 1990).

Total porosity supplies the most elementary information concerning the relative proportion of solids, water and air. The total porosity of soils is the fraction of the soil sample volume not occupied by the oven dry solids. The following equation is used to calculate the total porosity of soil samples:

$$f_T = 1 - (V_S/V_T) \qquad (1)$$

Where:

V_S = Volume of solids of a soil sample, m^3

V_T = Bulk volume of soil sample, m^3

f_T = Total porosity of a soil sample.

Air permeability is very sensitive to changes in porosity, and bulk density and can be measured quickly (Nau, 1987; Morgan, 1988). For this reason, it has been recognized as a soil property affected by compact stress and used as an index of compaction.

Methods of Soil Sampling

The most important engineering properties required for agricultural engineering purposes and foundation design are soil strength, compressibility, and permeability. Reasonably good estimates of these properties for cohesive soils can be made by laboratory tests on undisturbed samples which can be obtained with moderate difficulty.

The most widely used method of soil sampling is boring holes into the ground from which samples may be collected for either visual inspection or laboratory testing. The earliest method of obtaining a test hole was to excavate a test pit using a pick and shovel. Because of economics, the current procedure is to use power excavation equipment to excavate the pit and then to use hand tools to remove a block sample or shape the site for in situ testing. This is considered the best method at present for obtaining quality undisturbed samples.

Several procedures are commonly used to drill the holes and to obtain the soil samples. Among these methods, the following are used the most: auger, core sampler, thin wall tube and scraper bucket. Auger boring is the simplest method of making exploratory boreholes. Hand auger can be used for soil exploration work, for soil identification and water content above water table. The soil samples obtained from such borings are highly disturbed. In non-cohesive soils or soils having low cohesion the walls of the boreholes will not stand unsupported. In such circumstances, a metal pipe is used as casing to prevent the soil from caving in.

The core sampler provides a simple method for collecting disturbed soil samples in liners. In this method an open-ended cylindrical core is hammered into the soil. Then it is excavated from the soil. This method may be used for sampling at the surface or from the bottom of a predrilled hole using a slide hammer and extension. In dry loose soils the core catcher is used to prevent loose soil sample during recovery to the surface.

Thin wall tubes are sometimes referred to as *shelby tubes*. They are made of thin walled seamless steel with sharpened bottom end tubing. They are commonly used to obtain relatively undisturbed clayey soils. The tubes can be attached to drilling rods where the drilling rod with the sampler attached is lowered to the bottom of the borehole and the sampler is pushed into the soil. The soil sample inside the tube is then pulled out. Samples obtained in this manner may be used for consolidation or shear test, but sometimes the soil sample lost in soft clay and loose sand.

When soil deposit is sand mixed with gravel, obtaining samples by split spoon with a spring core catcher may not be possible because the pebbles may prevent the springs from closing. In such cases, a scraper bucket has a driving point and can be attached to a drilling rod. The sampler is driven down into the soil and rotated, and the scrapings from the side fall into the bucket.

Materials and Methods

Design and Operation of Soil Core Sampler

The purpose of this paper is to describe the design and operation of a soil core sampler that is hydraulically-powered for rapidly measuring and analyzing soil physical properties.

A soil core sampler (**Figure 1**) was designed in the workshops of Jordan University of Science and Technology to overcome the difficulty of gaining a coherent understanding of the soil compaction by agricultural vehicles due to the wide and confusing variety of methods used to study the subject. The hydraulic actuation of the coring probe reduces the physical effort required by the operators and the time required to make measurements. In addition, more accurate data over the manual sampling method are obtained. **Figure 2** shows a diagram of the soil core sampler consisting of a frame mounted by a tractor three-point hitch to operate in remote locations such as planted fields. The system will rapidly collect the soil samples from the ground at different depths.

Fig. 1 The hydraulically-powered soil core sampler mounted on a tractor.

The major parts of the probe assembly were made of steel because of its durability. The 2.5-cm diameter steel guide rods on each side of the hydraulic cylinder maintain the direction of the coring probe in the vertical direction and protect the cylinder rod from bending. The probe assembly slides horizontally on a 1.5-cm thickness × 60 cm × 12 cm rectangular steel slide rail. This slide rail was welded to two adjustable height legs at each end, which are capable of raising and lowering the sampler. The legs are raised and lowered by a screw jack, powered by the PTO shaft of the tractor (to which the sampler is hitched, hence provides the hydraulic force) through a bevel gear box and a warm gears set. The gearbox is equipped with a dog clutch that is engaged with either bevel gear to change from lowering to raising and vice versa. Raising the legs provide external force transmitted from the tractor to hold the frame on the ground so that the soil reaction force will not raise the frame from the ground during sampling. The coring probe was designed to hold the tapered sample tubes. These tubes were made of aluminum with length of 6 cm and 5-cm diameter as shown in **Figure 3**. A KUBOTA M8030 tractor was used to provide the hydraulic power to the double acting cylinder.

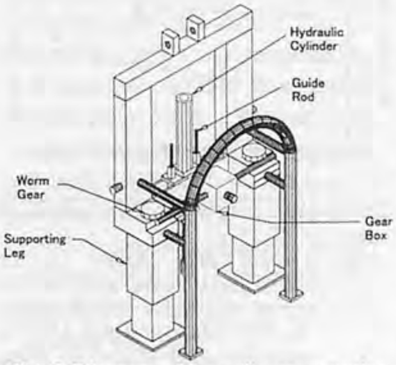


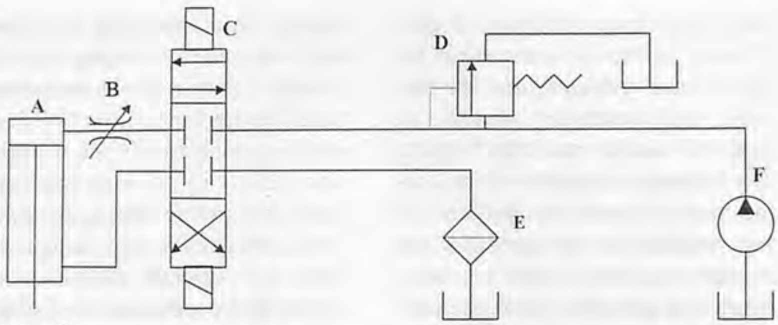
Fig. 2 Diagram of the soil core sampler.

The hydraulic system of the hydraulically-powered soil core sampler (HPSCS), which is part of the hydraulic circuit of the KUBOTA tractor, is a closed system. **Figure 4** shows the hydraulic circuit of the HPSCS system. It consists of a hydraulic pump with a reservoir and filter at the rear of the tractor. The hydraulic oil is transported via hydraulic lines to a 4-way, 3-position, solenoid operated, directional control valve and a pressure control valve stacked on a valve block mounted on the probe assembly. These valves operated a 3.81 cm bore by 91.44 cm stroke Parkertron hydraulic cylinder that is attached directly to the coring probe. The pressure control valve is used to set the maximum pressure at the cylinder in order to minimize damage to the coring tubes when a rock or other obstruction is encountered.

During operation, 10 soil cores were removed, one at a time, from each sample hole using the soil core sampler in an average time of 10 minutes. Thus, each core sample represented 5 cm of the 50-cm profile. Any soil clinging to the sides of the sample tube was wiped off and if any of the sample tubes were bent from hitting a rock, the tubes were replaced before the next use

Field Experiment Description

The experiment described below was designed to compare soil physical properties of soil samples ob-



Legend:
A = hydraulic cylinder
B = flow valve
C = directional valve
D = check valve
E = oil tank
F = pump

Fig. 3 Schematic diagram of the hydraulic circuit for the soil core sampler.

tained by the hydraulically powered soil core sampler with physical properties of soil samples obtained by a manually operated tool. The changes in soil physical properties caused by a KUBOTA M8030 tractor with 18.4 R30 tires at 100 kPa with a loaded 1500-kg planter mounted on the tractor were measured. The experiment was conducted on clay loam soil and the trafficking was repeated to provide three passes in the same track

The soil properties beneath the center of the tire tracks and in the untrafficked area between tracks were measured using the hydraulically powered soil core sampler and by a manually operated tool. Cores used in the manually operated tool were 5 cm in diameter and 5 cm in length. Four replicated measurements at each depth were taken in the wheel track and between the wheel tracks. A total of 80 samples were collected using the HPSCS and another 80 samples were collected using the manually operated tool for comparison. Bulk density and total porosity for the top 50 cm were analyzed to determine how the soil responded to the tractor traffic.

Wet bulk density of soil sample was obtained by weighing the known volume of the core filled with soil and then subtracts the weight of the core itself. Additional soil samples at each depth were retained for subsequent moisture content evaluation using the oven drying technique. The dry bulk density for each soil sample was then calculated using wet bulk density and moisture content values. The volume of solids was calculated by measuring the specific gravity of soil samples. Total porosity for each soil sample was measured using the volume of solids, the volume of water, and total sample volume.

Analysis of Results

Soil response for the KUBOTA M8030 tractor with 18.4 R30 tires at 100 kPa inflation pressure with a 1500-kg mounted-planter is shown in **Figure 4** for dry bulk density and **Figure 5** for total porosity. The data for each measured property were compiled and individual values were averaged for each 10-cm depth increment to a depth of 50 cm. Thus, each point on the curves represents the average of eight replicates.

Figure 4 shows how bulk density obtained by the two sampling methods was significantly increased due to the wheel traffic. The effect of the tractor traffic is evident down to 50 cm. A statistical analysis performed on the experimental data using MINITAB (1994) shows that bulk density under the center of the tire track is significantly different from the untrafficked at all depths ($p \leq 0.1$) for the two sampling methods. This is similar to the results obtained by Wood et al., (1993). Another analysis was performed at a 10% level of significance on the data obtained at each depth by the two sampling methods. The null hypothesis was that the data at each depth for the two sampling methods have the same mean. In general, there was no statistical difference

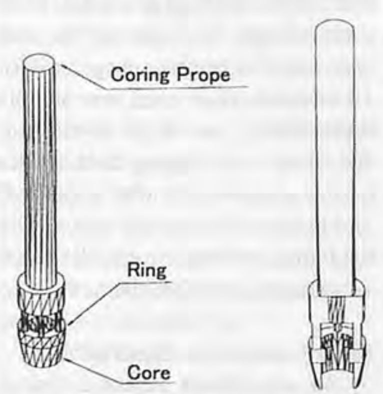


Fig. 4 Schematic diagram of the soil sampler probe.

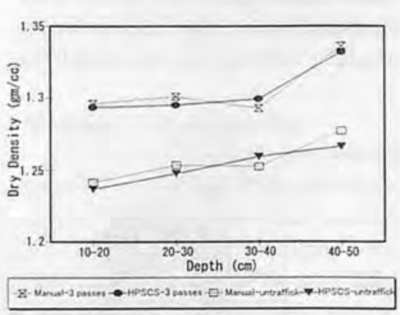


Fig. 5 Soil dry density in the untrafficked area and in the center of tire for loaded tractor @ 100 kPa using the HPSCS sampling method and by using manual sampling method.

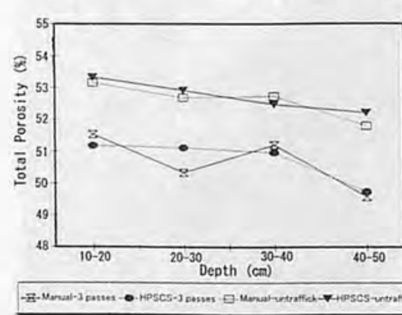


Fig. 6 Soil porosity in the untrafficked area and in the center of tire for loaded tractor @ 100 kPa using the HPSCS sampling method and by using manual sampling method.

Fig. 7 A tractor operator starting to let go the HPSCS.

Fig. 8 The HPSCS shown hitched behind the tractor ready to probe soil sampler.

Fig. 9 The HPSCS in action-view from the top.

among these sets of data at equivalent depths.

The tractor significantly reduced total porosity ($p \leq 0.1$) to a depth of 50 cm for both sampling methods. The statistical analysis showed no difference between data sets obtained by both sampling methods at each depth. The time required to sample 10 soil cores in the field using the hydraulically-powered soil core sampler was found to be 10 minutes, on the average.

Conclusions

The results from the field compaction study show that the hydraulically powered soil core sampler was capable of collecting soil samples in the field to measure soil physical properties using the hydraulic and mechanical power by an available tractor. The hydraulic actuation of the coring probe reduced the physical effort required by the operators and the time required making measurements. The average time required in the filed to collect 10 soil samples, 5 cm in diameter by 5 cm in length, was approximately 10 minutes. The bulk density and total porosity data from this field experiment showed that significant effects were present down to a depth of 50 cm due to trafficking the field by a tractor equipped with loaded grain drill mounted on it.

REFERENCES

Gupta, S.C., A. Hadas, W.B. Voorhees, D. Wolf, W.E. Larson and P.P. Sharma. 1990. Development of Guides on the Susceptibility of Soils to Excessive Compaction. University of Minnesota BARD Report. St. Paul.

Freitag D.R. 1971. Methods of Measuring Soil Compaction. pp. 47-103. In K.K. Barnes et.al (ed) Compaction of Agriculture Soils, ASAE Monograph, ST. Joseph, MI.

Jamison, V.C., Weaver, H.H. and Reed, I.F., 1950. A hammer-driven soil core sampler. Soil Sci., 69: 487-496.

Kunnemann, D. And Wittmuss H. 1976. Soil Structure Defined by Air Permeability. ASAE Paper No. 76-1515. St. Joseph, MI.

Lutz, J.F., 1947. Apparatus for collecting undisturbed soil samples. Soil Sci., 64: 399-401.

Nau, K. R., 1987. Air permeability: A measure of soil compaction. M.S. Thesis. The Ohio State University, columbus, Ohio, (unpublished), 133 pp.

Ngunjiri, G.M. and J.C. Siemens. 1993. Tractor Wheel Traffic Effects on Corn Growth. ASAE Paper No. 93-1110. Asae, ST. Joseph, MI

Mckibben, E.G. 1971. Introduction. pp 3-6. In K.K. Barnes et.al (ed). Compaction of Agriculture Soils. ASAE Monograph, St. Joseph, MI.

Morgan, M.T. 1988. A Soil Compaction Evaluation System for Rapid Field Measurement of Porosity, Density, Air Permeability, and Cone Index. Unpublished M.S. Thesis. The Ohio State University, Columbus, OH.

Morgan, M.T., R.G. Holmes, and R.K. Wood. 1993. A System for measuring soil properties in the field. Soil Tillage Res. 26: 301-325.

MINITAB. 1994. Minitab Release 10.2. Minitab Inc. State College, PA.

Soane, B.D. and J.D. Pidgeon. 1981. Tillage requirement in relation to soil physical properties. Soil Sci. 119(5): 376-384.

Tessier, S. and Steppuhn, H., 1990. Quick-mount soil core samplfor measuring bulk density. Can. J. Soil Sci., 70: 115-118.

Wells, L.G. and E.C. Burt. 1984. Response on Selected Soils to Power Tires at Disparate Moisture Conditions. ASAE Paper No. 84-1546. St. Joseph, MI.

Wood, R.K., R.C. Reeder, M.T. Morgan, and R.G. Holmes. 1993. Soil Physical Properties as Affected by Grain Cart Traffic. Transactions of theASAE;36(1):11-15. ■■

Tractive Performance of Power Tiller Tyres

by
Dr. K. Kathirvel
Assistant Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University,
Coimbatore
India

Dr. R.Manian
Professor
College of Agricultural Engineering
Tamil Nadu Agricultural University,
Coimbatore
India

Dr. M. Balasubramanian
Dean
College of Agricultural Engineering
Tamil Nadu Agricultural University,
Kumulur
India

Abstract

The tractive performance of the power tiller was measured in tilled and untilled soil conditions with three different size of tyres (5.00 × 12 - 2 PR, 5.00 × 14 - 2 PR and 6.00 × 12 - 4 PR) at 3/4th rated speed of the engine. The forward speed and slip were measured in the field at different levels of drawbar load and the tractive efficiency was computed. The tractive efficiency has been plotted as a function of slip for analysing the influence of tyre size on tractive performance of power tiller. From the experimental results it is concluded that the larger diameter tyre performed better than the smaller diameter tyres in improving the tractive efficiency. An increase of 17 percent in diameter of the tyre resulted in an increase of 7 to 23 per cent and 14 to 35 per cent tractive efficiency in untilled and tilled soil condition, respectively. An increase of 20 per cent in width of tyre resulted in an increased tractive efficiency of 3 to 13 per cent. The effect of tyre width in increasing the tractive efficiency is relatively less as compared to the tyre diameter. In untilled soil, higher tractive efficiency of 58 to 64 per cent occurred in the slip range of 10 to 15 per cent but in the tilled soil, a 15 to 25 percent slip produced tractive efficiency in the range of 58 to 61 per cent.

Introduction

The drawbar is the most commonly used power outlet of agricultural vehicles. The ability to provide draft to pull various types of implements is a primary measure of the effectiveness of a tractor or power tiller. The tractive efficiency with which the pull is achieved is of utmost importance for the agricultural vehicles. Tractive performance of a tyre depend on the type and surface condition of the soil, the tyre physical parameters and tyre loading. Traction is obtained from the forces transmitted through the soil-tyre interface. Experimental evidence indicates that the soil has a greater influence on the traction capabilities than the tyre design features. However, within a given soil type and condition, the tyre design parameters mainly the tyre size, has a significant effect on the tractive performance. In this paper an attempt has been made to assess the tractive efficiency of different size of tyres and the extent of influence of tyre size on the tractive efficiency of power tiller.

Review of Literature

Taylor *et al.*, (1967) reported that at the same normal load and inflation pressure, increasing diameter led to increased pull and tractive co-efficient. Taylor (1973) analysed the effect of lug angle on traction performance of pneumatic tractor tyres by conducting tyre with lug angles of 40, 50, 60, 70 and 80 degrees and concluded that the effects of lug angle on traction performance was negligible. Dwyer *et al.*, (1974) analysed the tractive performance of five sizes of tyres, measured in 13 field conditions and the results indicated that the tractive efficiency can be increased to approximately 70 per cent by doubling the diameter or section width. Taylor (1974) conducted field tests with pneumatic tyres of a tractor having 20, 23, 26, 29 and 32 lugs and concluded that in Lakeland loamy sand, Lloyd clay and Decatur silt loam soils, there was no indication that the lug spacing affected the tractive performance. Domier (1978) analysed the tractor performance results and reported that an increase of 10 and 18 per cent in tyre diameter resulted in an increase of 1.0 and 1.6 per cent increase in tractive efficiency. Steiner (1978) reported that the greatest effect on the tractive co-efficient was contributed by the tyre diameter. Gee Clough *et al.*, (1982) concluded that the larger tyre dimensions increased tractive performance. Dwyer (1984) reported that the effect of diameter in increasing the drawbar pull was demonstrated by an increase of 13 per cent for 18.4 × 38 tyre as compared to 18.4 × 30 tyre. But the effect of width in increasing the drawbar pull (DBP) was only 2 per cent higher for 16.9 × 30 tyre when compared to 12.4 × 36 tyre. Dwyer (1987) compared the tractive performance of 18.4 × 38 and 20.8 × 38 size tyres reported that the best performance was achieved by the 20.8 × 38 tyre and the maximum tractive efficiency was 73 and 70 per cent, respectively, for 20.8 × 38 and 18.4 × 38 tyres. Wolfsohn *et al.*, (1988) reported that the peak values of tractive efficiency occurred at higher values of slip for small tyres than the larger tyres. For the larger tyres the peak tractive efficiency was attained at approximately 10 per cent slip. The maximum tractive efficiency for small tyres occurred, on average, at 14 per cent slip. Bashford *et al.*, (1993) compared the tractive efficiency of a tractor equipped with three different size rear tyres (18.4 × 42, 18.4 × 46 and 12.4 × 54) on two different surfaces (wheat stubble and plowed wheat stubble) and reported that on firm and soft soils, the larger diameter tyres performed better than the smaller tyres. Arturo Lara Lopez (1996) evaluated a high clearance Mexican design 9 kW two wheeled tractor for performing different field operations and reported that a maximum tractive efficiency of 68.5 per cent and draft of 180 kg can be obtained at a slip value of 14.07 per cent for ploughing operation.

Wood and Mangione (1992) investigated the benefits of properly adjusted inflation pressures of tractor tyres and observed improvements in fuel use and field capacity with recommended tyre inflation pressures when compared with tyres operated at high inflation pressures.

Materials and Methods

For the assessment of tractive efficiency of the power tiller in field conditions, the axle horse power has to be measured while the power tiller is performing its function in the field. Since mounting of the torque transducer on one wheel axle of the power tiller and operating it in the field is very difficult as it affects the stability of the unit, the axle horse power was measured at different gear positions and at the recommended 3/4th rated speed of the engine (1500 rpm) in the laboratory conditions.

Tyre Size

Experimental evidence indicates that the tyre size has an influence on the traction capabilities. Investigations carried out to determine the effect of diameter on the tractive performance reveal that increasing the diameter of wheel increases the maximum pull and the tractive coefficient. The larger tyre dimensions allowed extra weight to be added by ballasting which could be carried in the tyres. Increasing tyre width increases the flexibility of the tyre and generally assists in the uniformity of pressure application, helping in increased traction capabilities. The tractive efficiency can be increased by doubling the diameter of the tyre. Hence the three size of tyres commercially available for power tillers are a) 5.00 × 12 - 2 PR; b) 5.00 × 14 - 2 PR; and c) 6.00 × 12 - 4 PR were selected for the study. These tyres vary in their width and diameter. The details of the tyre geometry for the above three tyres are furnished in **Table 1**.

Table 1. Details of Tyre Geometry

Tyre geometry	Tyre 1(T_1)	Tyre 2(T_2)	Tyre 3(T_3)
Tyre size	5.00 × 12-2 PR	5.00 × 14-2 PR	6.00 × 12-4 PR
Tyre ply	2 PR	2 PR	4 PR
Lug spacing, mm	90	126	120
Lug angle, degree	55	55	60
Lug height, mm	14.5	17.0	16.0

Research investigations carried out on the effect of lug angle and spacing on traction performance of pneumatic tyres reveal that the effect of lug angle and lug spacing are negligible. Also, it was observed that there was not much variation in lug height of the three tyres. The inflation pressure of tyre has long been recognized as an important variable in optimizing the performance of tractors. Research works on tractive performance have demonstrated the advantages of properly inflated tractor tyres. Significant gains in tractive efficiency can be achieved by following the load-inflation pressure data supplied by the manufacturers and setting inflation pressures to the recommended level. Excessive inflation pressure had resulted in the greatest reduction in the performance of the tractors. Hence, for the study, the manufacturers' recommended level of 1.2 kg/cm^2 tyre pressure was adopted.

SoiL Type and Track Condition

The tractive performance of power tiller tyres were evaluated in two types of soil predominant in the region of study viz., black clay loam soil and sandy loam soil. The mechanical analysis of the two soils indicated that the black cotton soil had a composition of 34, 10 and 36 per cent of clay, silt and fine sand, respectively, and hence a typical sandy clay loam soil. The red loam soil had 18, 16 and 34 per cent of clay, silt and fine sand and hence is a sandy loam soil.

For primary and secondary tillage operations the power tiller has to be operated in untilled and tilled condition of cultivable land. Hence the following two track conditions are selected:

a) Untilled condition - The soil was left as fallow land for six months after the harvest of the previous crop; and

b)Tilled condition - The fallow land was ploughed twice with a tractor drawn cultivator before conducting the experiment. The soil properties such as moisture content, bulk density and cone index were measured during the test. The moisture content of the soil was maintained in the range of 5 to 7 per cent. The bulk density, measured at 10 cm depth, defined the track condition of the soil. It's values in untilled and tilled conditions in sandy clay loam soil were 1.46 and 1.26 gm/cc, respectively, and the values for sandy loam soil were 1.50 and 1.35 gm/cc, respectively. The cone index values for the untilled and tilled condition in sandy clay loam soil were 9.32 and 2.31 kg/cm^2 and its value for sandy loam soil were 10.12 and 2.89 kg/cm^2, respectively.

Gear Position

The power tiller was operated and controlled in the field by an operator who walked behind it. The normal walking speed of the operator in the field was around 2.5 kmph. For effective and efficient maneuverability in the field, the power tiller has to be operated at a forward speed of about 2.5 kmph only, which occurred in the gear position range of Low I to Low III. Hence, the low range of gear positions viz., Low I (G_1), Low II (G_2) and Low III (G_3) were selected for the study. The maximum forward speed corresponding to the above gear position were 1.2, 1.9 and 3.3 kmph, respectively.

Drawbar Load

The power tiller was mainly used for primary and secondary tillage operations like ploughing with a single bottom mould board plough, harrowing with a cultivator, bunding with a terracer blade and rototilling. These operations, done with power tiller operated-equipment require a draft ranging from 75 to 150 kg. Hence the trial was conducted at four different levels of drawbar load of 60, 90, 120 and 150 kg in untilled condition and it was limited to three levels in tilled condition due to higher slippage beyond 120 kg.

Field Tests and Measurements

During the field test with the test power tiller, the following parameters were measured:

DBP, wheel slip and forward speed.

a. Drawbar Pull (DBP)

A loading car consisting of power transmission system and hydraulic loading system was developed and the drawbar load was applied precisely to the desired levels. It was capable of applying a drawbar load accurately from 40 to 200 kg at an increment of 5 kg. A hydraulic dynamometer mounting frame was also developed and it was mounted in between the power tiller and the loading car. The drawbar pull developed by the power tiller was monitored from the dynamometer reading.

b. Wheel Slip

The slip of the power tiller was measured by monitoring the number of revolutions of the wheel over a distance of 30 meters under load and no load conditions. The revolutions made by the wheel was fed to a revolution counter through a speedometer cable. The revolution counter was mounted at appropriate height for easy observation. The slip was calculated by using the following formula:

$s = [(n_1 - n_0) / n_0] \times 100$

where,

s = wheel slip, per cent

n_1 = Number of revolutions of wheel under load for a distance of 30 m

n_0 = Number of revolution of wheel under no load for a distance of 30 m.

c. Forward Speed

The forward speed of operation was calculated by observing the distance traveled and the time taken as follows.

$S = L / t$

where,

S = Forward speed of operation, m/sec

L = Distance traveled, m

t = Time taken, sec

d. Drawbar Horse Power (DBHP)

The DBHP for each run was calculated by using the following formula:

$DBHP = [(DBP)S / 75] \times 0.746$

where,

DBHP= Drawbar horse power, kW

DBP = Drawbar pull, kg

S = Forward speed of operation, m/sec

e. Axle Horse Power (AHP)

For computing the tractive efficiency of the power tiller, the AHP has to be measured while the power tiller was performing its function in the field. Since mounting of the torque transducer on one wheel axle of the power tiller and operating it in the field is very difficult as it affects the stability of the unit, the AHP was measured at different gear positions in the laboratory conditions. The variation in the engine speed of the power tiller during the field test was measured by using a "PRICOL" make speedometer with a range of 0 to 10000 rpm. It was connected to the clutch pulley shaft by means of cable. The axle power corresponding to the observed engine speed in the field, was taken from the results of the laboratory tests conducted.

f. Tractive Efficiency (TE)

The tractive efficiency of the power tiller was calculated by using the following expression:

TE = (DBHP / AHP) × 100

where,

TE = Tractive efficiency, per cent

DBHP= Drawbar horse power, kW

AHP = Axle horse power, kW

Results and Discussion

The tractive efficiency and slip were the parameters used for the evaluation of the tractive performance of power tiller tyres. Hence, the tractive efficiency is plotted as a function of slip. As the tyre size plays a significant role in influencing the tractive performance of the power tiller, the performance curves for the selected three size of tyres at gear positions G_1, G_2 and G_3 in untilled and tilled conditions of black clay loam and sandy loam soil are drawn and presented in **Figures 1 to 4**.

From the figures it will be observed that the tractive efficiency of the larger diameter tyre T_2 is higher than the other two tyres T_1 and T_3 in all the conditions tested. Comparing the tractive performance of the tyres T_1 and T_3, the performance of higher width tyre T_3 is better than tyre T_1. The performance values at 15 per cent slip on the test tracks is computed from the figures as specified by the standard test codes and presented in **Table 2**.

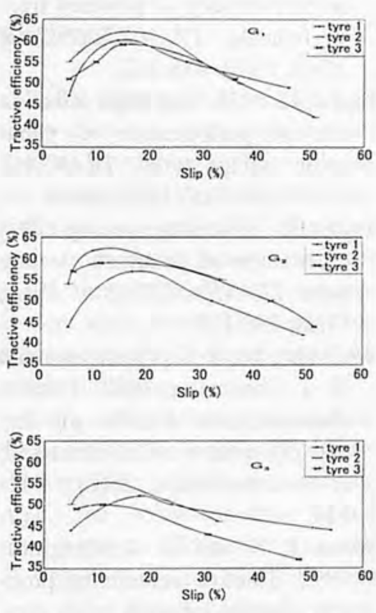


Fig. 1 Tractive performance of power tiller tyres in untilled black clay loam soil.

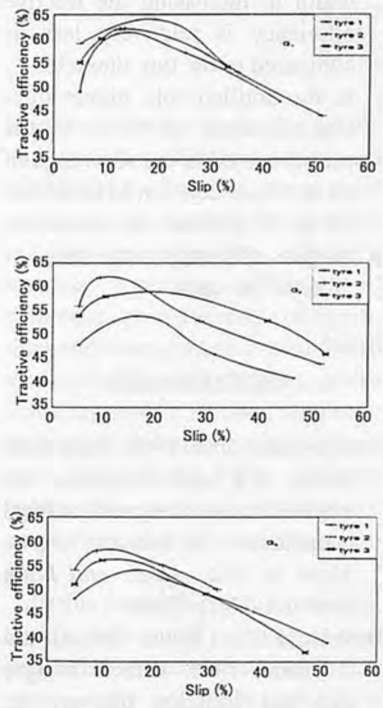


Fig. 2 Tractive performance of power tiller tyres in untilled sandy loam soil.

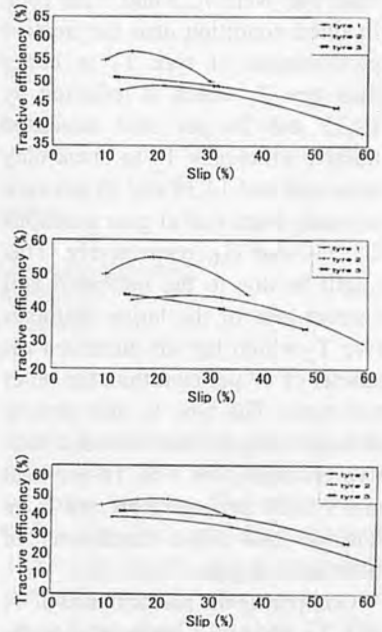


Fig. 3 Tractive performance of power tiller tyres in tilled black clay loam soil.

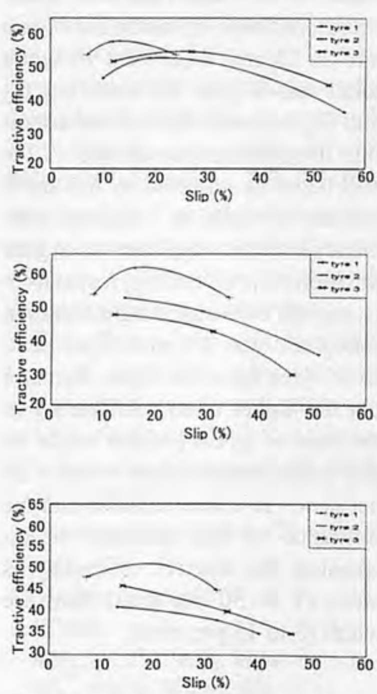


Fig. 4 Tractive performance of power tiller tyres in tilled sandy loam soil.

Table 2. Tractive Efficiency of Power Tiller Tyres at 15 Per Cent Slip

Tyre	Black clay loam soil Gear positions			Sandy loam soil Gear positions		
	G_1	G_2	G_3	G_1	G_2	G_3
I. Untilled condition						
T_1	58	56	49	60	52	54
T_2	62	62	54	64	64	58
T_3	60	59	51	62	58	56
II. Tilled condition						
T_1	48	43	38	51	47	40
T_2	57	58	48	58	61	50
T_3	51	45	41	52	51	45

It is inferred from the table that the tractive efficiency of tyre T_2 is higher by 7,11 and 10 per cent than tyre T_1 in untilled condition of black clay loam soil at gear positions G_1, G_2 and G_3, respectively. The corresponding figures in sandy loam soil were 7,23 and 7 per cent. In tilled condition also the tractive performance of tyre T_2 is better than tyre T_1 which is reflected by 19,35 and 26 per cent increased tractive efficiency T_2 in black clay loam soil and 14,30 and 25 per cent in sandy loam soil at gear positions G_1, G_2 and G_3, respectively. This might be due to the increased soil contact area of the larger diameter tyre T_2 which has an increased diameter of 17 per cent than the other two tyres. The tyre T_2 also proved its superiority by the increased tractive efficiency of 3 to 11 per cent and 9 to 30 per cent than tyre T_3 in untilled and tilled conditions of both the soil types.

Comparing the performance of T_1 and T_3, it will be observed that the tyre T_3 performed better than tyre T_1 in developing higher tractive efficiency of 3, 5 and 4 per cent in untilled condition of black clay loam and 3, 12 and 4 per cent in sandy loam soil at gear positions G_1, G_2 and G_3, respectively. In tilled condition the performance of tyre T_3 is still better as reflected by 6,5 and 8 percent increase of tractive efficiency in black clay loam soil at gear positions G_1, G_2 and G_3, respectively, and the corresponding increase in sandy soil was 4,9 and 13 per cent. Both tyres have the same diameter but the higher tractive efficiency in the case of tyre T_3 which might be due to the increased tyre width of 20 per cent. It is also revealed that the influence of tyre diameter in increasing the tractive efficiency is more (7 to 30 per cent) than the width (3 to 13 per cent).

Conclusions

From the results of the study the following conclusions are drawn:

a. The larger diameter of tyre T_2 performed better than the smaller diameter tyres in improving the tractive efficiency. An increase of 17 percent in diameter of the tyre resulted in an increase of 7 to 23 per cent and 14 to 35 per cent tractive efficiency in untilled and tilled soil conditions, respectively.
b. An increase of 20 per cent in width of tyre T_3 resulted in an increased tractive efficiency of 3 to 13 per cent. The effect of tyre width in increasing the tractive efficiency is relatively less as compared to the tyre diameter.
c. In the untilled soil, higher tractive efficiency of 58 to 64 per cent occurred in the slip range of 10 to 15 per cent but in tilled soil 15 to 25 percent slip produced tractive efficiency in the range of 58 to 61 per cent.

REFERENCES

Arturo Lara Lopez. 1996. Field evaluation of a high clearance, two wheeled tractor designed for local manufacture in Mexico. *Agric. Mech in Asia, Africa and Latin America*, 27(1): 59-62.

Bashford,L.L., I.Abdul Hamed and C.Jenane, 1993. Effects of tyre size and inflation pressure on tractive performance. *J. Appl. Engng. Agric.* (USA), 9(4): 343-348.

Domier,K.W. 1978. Traction analysis of Nebrasca tractor tests. *TRANSCTIONS of ASAE*, 21(2): 244-248.

Dwyer,M.J., D.R.Comely and D.W.Evernden, 1974. The field performance of some tractor tyres related to soil mechanical properties. *J. Agric. Engng. Res.*, 19: 35-50.

Dwyer,M.J. 1984. The tractive performance of wheeled vehicles. *J. Terramechanics*, 21(1): 19-34.

Dwyer,M.J. 1987. The tractive performance of a wide, low pressure tyre compared with conventional tractor drive tyres. *J. Terramechanics*, 24(3): 227-234.

Gee Clough,D., G.Pearson and M.McAllister, 1982. Ballasting wheeled tractors to achieve maximum power output in frictional cohesive soils. *J. Agric. Engng. Res.*, 27: 1-19.

Steiner, M. 1978. Measurement of traction-slip curves of different farm tractor tyre in a soil bin. Messurgen for triebkraft-schlupf-kurven Grondlagen dev Land technique, 28(5): 169-178.

Taylor, J. H., G.E.Vandenberg and I.F.Reed, 1967. Effect of diameter on performance of powered tractor wheels. *TRANSCTIONS of ASAE*, 10(6): 838-842.

Taylor, H. 1973. Lug angle effect on traction performance of pneumatic tractor tyres. *TRANSACTIONS of ASAE*, 16(1): 16-18.

Taylor,H. 1974. Lug spacing effect on traction of pneumatic tractor tyres. *TRANSACTIONS of ASAE*, 17(2): 195-197.

Wolfsohn, D., S. K. Upadhyaya and W. J. Chancellor, 1988. Tractive characteristics of radial ply and bias ply tyres in a California soil. *J. Terramechanics*, 25(2) : 111-134.

Wood, R. K. and D. A. Mangione, 1992. Tractive benefits of properly adjusted inflation pressures. Paper ASAE, No. 92-1583 : 6.

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Some Effective Parameters on Separating Efficiency of Screw-conveyor Used for Separating and Transporting

by

Ahmet İnce
Research Assistant
Dept. of Agricultural Machinery
Faculty of Agriculture
Cukurova University
01330 Adana,
Turkey

Emin Güzel
Professor
Dept. of Agricultural Machinery
Faculty of Agriculture
Cukurova University
01330 Adana,
Turkey

Abstract

In the present study, designing a screw-conveyor separating system that can be adopted to the combines and examining some effective parameters on separating efficiency such as feed rate, screw-conveyor speed, screw pitch and moisture content were aimed. The separating efficiency was determined for wheat and barley.

It was shown that all evaluated parameters have significant effects on separating efficiency statically. Also, the screw-conveyor speed was a most effective parameter. The highest separating efficiencies were about 92% and 85% for wheat and barley, respectively.

Introduction

The biggest part of grain losses, except header losses, appeared during cereal harvesting, (Wrubleski and Smith, 1980; Huisman, 1983; Srivastava et all., 1993). At the ideal conditions and arrangements, straw-walker losses changed between 0.5-2% (Kilinç and Gölbasi, 1991). One of the reasons of straw-walker losses is that the separating process occurred at the straw-walkers is a probability function. This random process is affected by feed rate, straw-grain ratio, straw-walker length and material thickness on the straw-walker. To increase separating efficiency of combines, quite different configurations and arrangements are used such as ventilating and vibrating grain-straw mixtures and using supporter devices on the straw-walkers (Reed et al., 1974; Güzel, 1996). Unfortunately, the combine performance cannot be increased over certain limits.

In this research, to eliminate negativity mentioned above, a new separation system that can be to used in the combines instead of straw-walkers was developed and the effect of some design and operating para-meters on separating efficiency of system were evaluated.

Material and Methods

The experiment set was composed of a threshing unit and a screw-conveyor (**Fig.1**). It is fed by a belt conveyor that is 8,000 mm long and 660 mm wide. The threshing drum's diameter and length were 600 and 1,085 mm, respectively. For separating, the one-way screw-conveyor was used instead of straw walkers. The screw-conveyor was 260 mm diameter and 1,060 mm length. It was surrounded halfway with a concave cover made from sheet iron (**Fig. 2**). The separating concave has 20 mm holes. The gap between screw-conveyor and concave was 15 mm.

The crop material was laid on the conveyor ahead of the whole assembly and fed into the threshing drum by changing the quantity of material. The threshing drum was rotated with 800 rpm, constantly. The samples were collected under the threshing unit, screw-conveyor and at the rear of the set. The set was moved out until the entire materials came out.

The effect of the following factors on separating efficiency of screw-conveyor was evaluated:

1. MOG feed rate (Q) (1, 2, 3.5 kg/s),
2. Screw-conveyor speed (D) (250, 450, 650 rpm),
3. Screw-conveyor pitch (S) (15, 20 cm),
4. Moisture content (W_b);
   Wheat
   W_{1g}: 13.5%; W_{1s}: 11%
   W_{2g}: 9.6%; W_{2s}: 7.5%
   Barley
   W_{1g}: 14%; W_{1s}: 11.2%

W_{2g}: 9.7%; W_{2s}: 7.8%

The research materials were wheat and barley with randomized complete block design with three replications. The grain-straw ratio of the wheat and barley was 1/1.54 and 1/2.2, respectively.

Results and Discussion

The analysis of variance of the separating efficiency for wheat and barley is given in **Tables 1** and **2**.

Feed Rate

The separating efficiency was calculated for different feed rates. The results are shown in **Fig. 2**. Wherein, the curves are almost linear. In other words, there is an exponential relationship bet-ween separating efficiency and feed rate. When MOG feed rate increases, the separating efficiency decreases, consequently separating loss increases. Because, at high feed rates, the crop flow between screw-conveyor and concave is denser. This causes reducing the quantity of the separated grain. The difference bet-ween feed rates 3.6 t/h and 12.6 t/h is about 5% for both crop. This is remarkable considering timeliness. In addition, the feed rate has significant effect on separating efficiency at 1% and 5%, in wheat and barley, respectively.

In addition, at small feed rates the quantity of unthreshed kernel passed under screw-conveyor and left the screw-conveyor was quite low, but this situation changed at high feed rate.

Screw-conveyor Speed

The separating efficiency decreases when the screw-conveyor speed increases (**Fig. 3**). Because at small speed, travel time of the material increases. Thus, free grains have much more time to pass through the grates. Also, when the speed is small, the centrifugal force effect that obstruct the grain passing decreases. The screw-conveyor speed

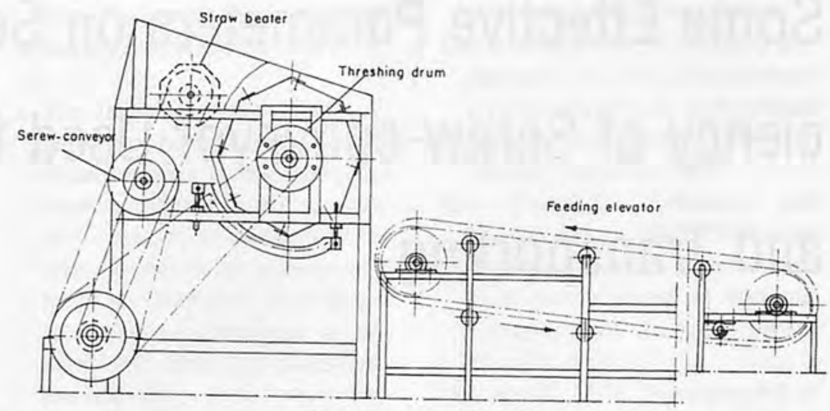

Fig.1 The experiment set.

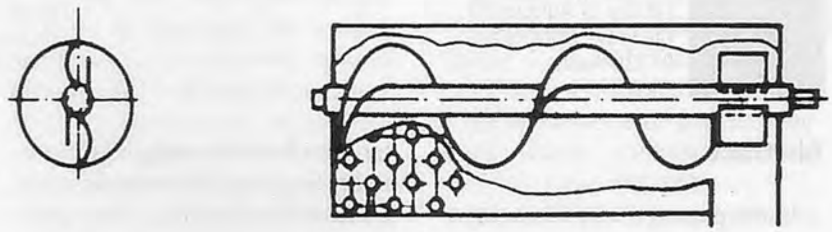

Fig. 2 Screw-conveyor and separating concave.

Table 1. Analysis of Variance Table for Wheat

Source	Degrees of freedom	Mean Square	F-ratio
Replication	2	5.951	4.6076*
Feed rate (Q)	2	230.04	178.7060***
Error	4	1.292	—
Screw-con. Speed (D)	2	974.070	95.4628***
Q × D	4	51.387	5.0361***
Error	12	10.204	—
Screw-con. Pitch (S)	1	8432.301	719.8947***
Q × S	2	9.959	0.8502
D × S	2	41.417	3.5360**
Q × D × S	4	41.319	3.5276***
Moisture (W)	1	72.194	6.1634***
Q × W	2	7.531	0.6430
D × W	2	160.482	13.7009***
Q × D × W	4	42.134	3.5971***
S × W	1	35.707	3.0485*
Q × S × W	2	37.344	3.1882**
D × S × W	2	12.254	1.0461
Q × D × S × W	4	4.175	0.3564
Error	54	11.713	—
Total	107	—	—

* 10 %;** 5 %;*** 1 %

Duncan test results

Q	Q1	73.53 a
	Q2	71.04 b
	Q3	68.47 c
D	D1	76.18 a
	D2	71.08 b
	D3	65.78 c
S	S1	79.85
	S2	62.17
W	W1	70.19
	W2	71.83

Table 2. Analysis of Variance Table for Barley

Source	Degrees of freedom	Mean Square	F-ratio
Replication	2	2.960	0.1153
Feed rate (Q)	2	170.549	6.6405**
Error	4	25.683	—
Screw-con. Speed (D)	2	570.485	50.8212***
Q × D	4	67.985	6.0564***
Error	12	11.225	—
Screw-con. Pitch (S)	1	733.203	55.2447***
Q × S	2	19.754	1.4884
D × S	2	414.280	31.2148***
Q × D × S	4	19.053	1.4356
Moisture (W)	1	457.979	34.5074***
Q × W	2	1.743	0.1313
D × W	2	58.160	4.3822***
Q × D × W	4	19.788	1.4910
S × W	1	4.813	0.3627
Q × S × W	2	4.502	0.3392
D × S × W	2	68.630	5.1711***
Q × D × S × W	4	24.795	1.8682
Error	54	13.272	—
Total	107	—	—
* 10 %;** 5 %;*** 1 %			
Duncan test results			
Q	Q1	68.19 a	
	Q2	66.29 b	
	Q3	63.85 c	
D	D1	70.27 a	
	D2	65.72 b	
	D3	62.34 c	
S	S1	68.71	
	S2	63.50	
W	W1	64.05	
	W2	68.16	

has a significant effect at 1% level for both crops (**Tables 1** and **2**).

Screw Pitch

Increasing travel time of the materials can also be achieved by reducing the screw pitch from 20 cm to 15 cm increases the way about 1.5 times. So, this causes increasing separating efficiency (**Fig. 5**). This difference is equal 40 cm way for 260 mm screw diameter. The screw pitch has also significant effect on separating efficiency at 1% level for wheat and barley (**Tables 1** and **2**).

Moisture Content

The separating efficiency decreases with moisture content (**Fig. 6**). This reduction is much less in wheat. One of the reasons of this case is that the wheat has smaller straw-grain ratio than barley. In addition, it is more difficult to thresh and separate barley than wheat at high moisture contents.

Threshing Efficiency of Screw-conveyor

Increasing the threshing efficiency of the system can be achieved by using the screw-conveyor. In fact, it is considered that the screw-conveyor is an axial threshing and separating unit.

The whole system's threshing efficiency was about 99% and 97% for wheat and barley, respectively. Increasing the MOG feed rate decreased the threshing efficiency of the whole system. But the portion of the threshing efficiency of the screw-conveyor was increased. This is because at low feed rates, the gap between the screw-conveyor and concave is not filled. Thus the impact of the screw-conveyor and friction efficiency decreases (Wacker, 1989). However, at high feed rates the thicker layer of crop makes grain separation more difficult.

Figure 7 shows the changing the portion of the threshing efficiency of the screw-conveyor depend on MOG feed rate and moisture content.

Conclusions

The screw-conveyor separating system can achieve both grain-straw separating and transporting. Moreover, the threshing efficiency of the system can increase by using a screw-conveyor. It was found that all evaluated parameters have significant effect on separating efficiency of screw-conveyor statically. This is the most effective

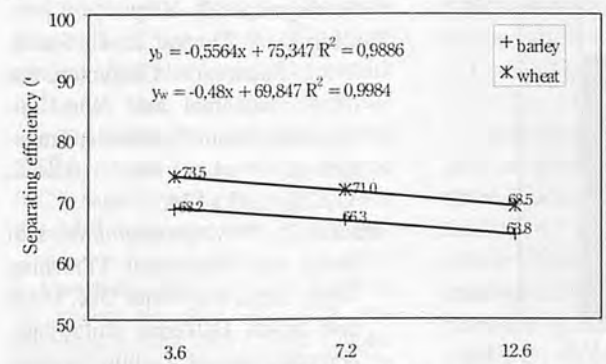

Fig. 3 Separating efficiency versus feed rate.

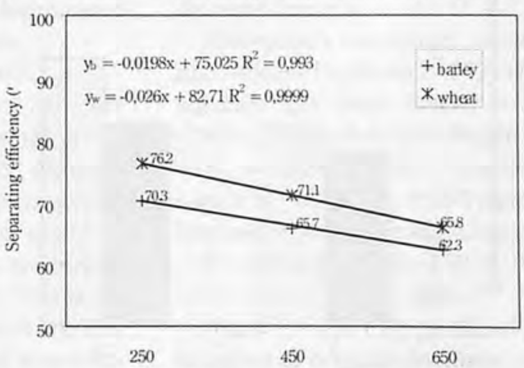

Fig. 4 Effect of screw-conveyor speed on separating efficiency.

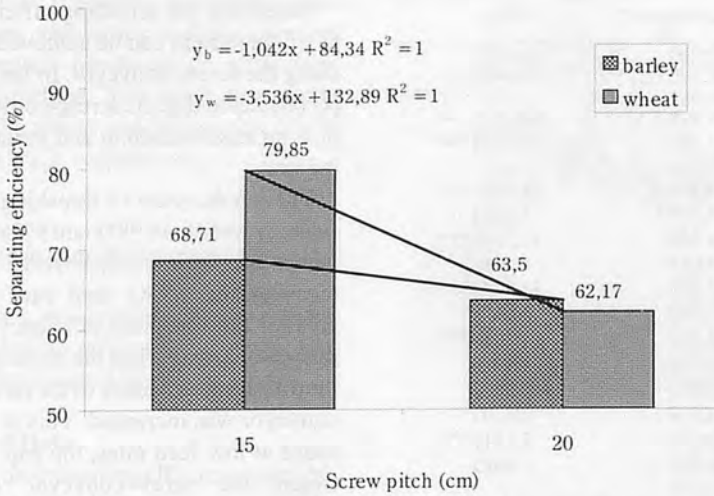

Fig. 5 Changing of separating efficiency with screw pitch.

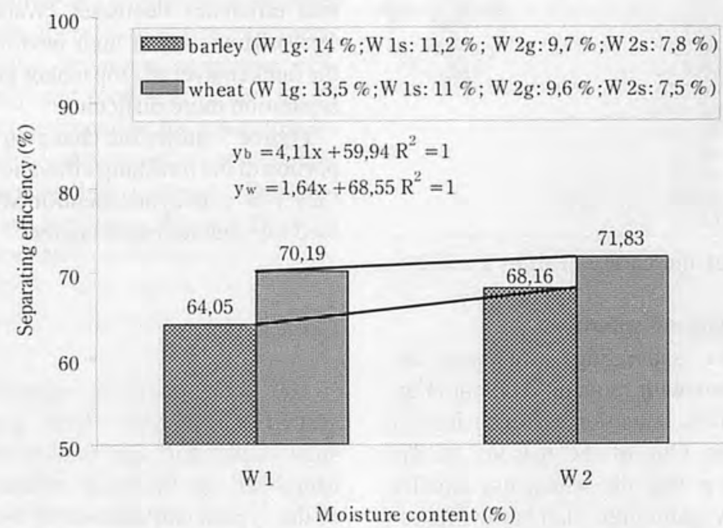

Fig. 6 Effect of moisture content on separating efficiency.

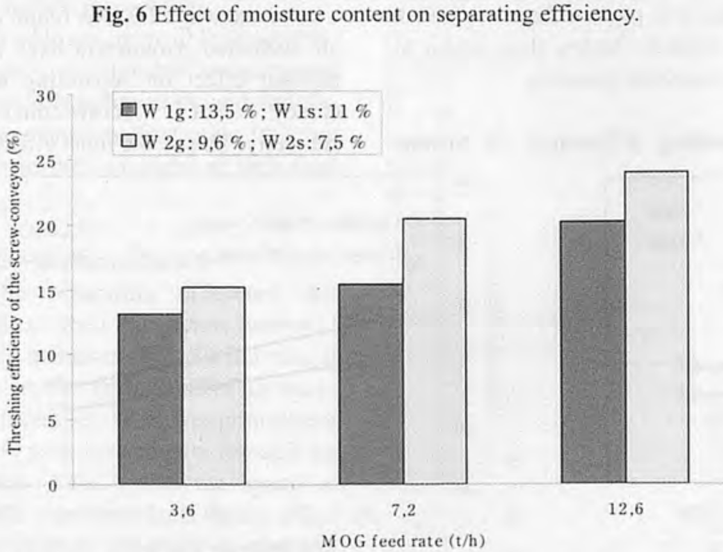

Fig. 7 Effect of MOG feed rate on threshing efficiency of screw-conveyor.

parameter is screw-conveyor speed. The highest separating efficiency for both wheat and barley was determined at $Q_1 \times D_1 \times S_2 \times W_2$ interaction. In other words, increasing the efficiency can be achieved by reducing the speed and screw pitch. In addition, there were quite less grain damage.

REFERENCES

Güzel, E., 1996. New Developments in Combine Technique. Univ. of Çukurova, Fac. of Agriculture, Dept. of Agriculture Machinery Seminars, 96/14, Adana.

Huisman, W., 1983. Optimum Cereal Combine Harvester Operation by Means of Automatic machine and Threshing Speed Control. Ph.D

Thesis, Dept. Of Agric. Eng., Agricultural Univ. Mansholtlaan 12, Wageningen.

Kilinç, K. S.; M. Gölbasi, 1991. Grain Losses in Cereal Harvest by Combines and Determination Methods. 13th National Congress on Agricultural Mechanization, 25-27 September, Konya. Pp389-400.

Reed, W. B.; G. C. Zoerb; F. W. Bigsby, 1973. A Laboratory Study of Grain-Straw Separation. Transaction of the ASAE, Vol.17(6):452-460

Srivastava, A. K.; C. E. Georing; R. P. Rohrbach, 1993. Engineering Principles of Agricultural Machines, Published by ASAE, Michigan, USA. 600p.

Wrubleski, P. D. and L. G. Smith, 1980. Separation Characteristics of Conventainal and Non-Conventional Grain Combines. Transactions of the ASAE, Vol.23(3):530-534.

Wacker, P., 1989. Quality of Work of Axial and Tangential Threshing Units. Land and Water Use, Dodd and Grace, Balkema, Rotterdam, (Proceedings of Dublin Conference, CIGR), pp1863-1868.

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Deterioration Rates of Wheat as Measured by CO_2 Production

by
S. A. Al-Yahya
College of Agriculture and Veterinary Medicine,
King Saud University
(Gassim Branch), Buraidah
P. O. Box 1482, Saudi Arabia
Fax:(+966) 6-3801360

Abstract

Carbon dioxide(CO_2) production was used as an indicator to determine the allowable storage time (AST) for wheat under different conditions such as temperature, moisture, and mechanical damage. Four grain moisture contents were used which are 15, 18, 21, and 24%. The four temperature levels used were 4, 15, 25, and 40 C°. Three levels of percentage of mechanical damage were used which are 0, 15, and 30%. Each level of moisture was tested in three replicates with each degree of temperature and level of mechanical damage. The system used to determine CO_2 production is the same one used by Al-Yahya et al. (1993). Statistical comparisons were made in regard of the AST between the levels of temperature, moisture, and mechanical damage. The analysis showed significant difference among all of the levels. The results indicated that the AST was increased with low moisture level (15%), low temperature degree (4C°), and low damage (0%). But the AST decreased with high moisture level (24%), high temperature degree (40C°) and high damage (30%). Tables and equations were developed to easily calculate the AST or deterioration rate under any storage conditions.

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Introduction

Carbon dioxide is a product of respiration of the grain storage and from the respiration of micro-organisms. Baily and Gurjar (1918) determined CO_2 production as a quantitative method for measuring the rate of respiration in wheat. They sealed wheat samples of known moisture content in jars and used barium hydroxide solution to absorb CO_2. The respiration rate was expressed in terms of mg CO_2 respired per 100 g dry matter per 24h. The complete combustion of a typical carbohydrate is represented by the following equation:

$$C_2H_{12}O_6 + 6O_2 > 6CO_2 + 6H_2O + 677.2 \text{ cal} \quad (1)$$

According to equation (1), a 1% loss in grain dry matter carbohydrate is accompanied by the evolution of 14.7 g CO_2 / kg of grain dry matter. Carbon dioxide production can be easily measured. This is the reason why many research workers used CO_2 as an index of deterioration rate in grain. These are Saul and Lind (1958), Saul and Steele (1966), Steele (1967), Fawole (1969), Seitz et al. (1982), Fernandez et al. (1985), Friday et al. (1989), Al-Yahya et al. (1993), and Aljinovic et al. (1995). It is desirable to know how much time to run the experiment in order to obtain a specific quantity of CO_2 production. In the 1955 and 1956 tests conducted by Saul and Lind (1958), the grain was said to be in good condition if during drying the grain had lost less than one percent of its initial dry weight. Saul and Steele (1966) mentioned that 0.5% loss of dry matter can be sustained without causing a reduction in mark grade for mold damage. Steele et al. (1969) studied the factors affecting CO_2 evolution in stored corn by both grain respiration and microorganism growth. These factors included grain moisture content, grain-storage temperature, and mechanical damage.

Thompson's computer simulation model (Thompson, 1972) used equation (2) from Steele et al. (1969) to calculate the weight of CO_2 produced at the "standard" condition of 25 C°, 15.5 % moisture and 30% mechanical damage.

$$Y = 1.3\,[\exp(0.006t) - 1\,] + 0.015t \quad (2)$$

where Y= g of CO_2 produced per kilogram of original dry mater, and t = time. He came up with the **Table 1**. Up to now, there is no litera-

Table 1. Allowable Storage Time for Stored Corn in Days, Thompson (1972)

Grain temperature (C°)	Grain moisture content, %						
	18%	20%	22%	24%	26%	28%	30%
-1	648	321	190	127	94	74	61
2	432	214	126	85	62	49	40
4.5	288	142	84	56	41	32	27
7	192	95	56	37	27	21	18
10	128	63	37	25	18	14	12
13	85	42	25	16	12	9	8
16	56	28	17	11	8	7	5
18	42	21	13	8	6	5	4
21	31	16	9	6	5	4	3
24	23	12	7	5	4	3	2
27	17	9	5	4	3	2	2

ture on CO_2 production as an index to determine the deterioration rate or the allowable storage time of the stored wheat under various storage conditions.

The objective of this study was to determine the allowable storage time of stored wheat under different storage conditions such as grain moisture content, grain-storage temperature, and grain-mechanical damage.

Experimental Procedure

Variety Selection

Yoka Ra Rogo is the most common wheat variety grown in Saudi Arabia, which is why it was selected for this experiment. The wheat was grown at the Research Station which belongs to the Agriculture and Veterinary medicine College in Gassim- Saudi Arabia. It was sown in November 1995 and hand-harvested in March 1995.

Sample Preparation

After harvesting, the kernels were removed by hand-shelling. The samples were then passed through Carter Dockage Tester to remove any fines, light material, or foreign grains. All damage kernels such as large broken kernels and those damage by insects or infected by field fungi were also removed. The remaining kernels were assumed to have 0% mechanical damage. The samples were kept at -10C° storage until testing. According to Fernandez et al. (1985), corn stored at -10C° responds to storage fungi almost the same as freshly harvested corn. Since there is no a available data for wheat, it is assumed that this degree of temperature is good for other grains.

Storage Rooms

Five storage rooms (3 × 2 × 2 m) were built for this experiment. They were built in the same station mentioned above. The temperature in each room was very well controlled. Temperature of these rooms were 4,15,25,40 and -10C°. The last temperature was used to keep the samples as freshly harvested.

Grain-moisture Content

The moisture content of grains at harvesting was about 9%. The grains were kept at low level to make sure that these samples will be free of any storage fungi during entire the experiment period which was about two years. At the beginning of each experiment, the samples were thawed and the desirable moisture level was achieved by adding the exact required quantity of water. The sample was thoroughly mixed for 12h. Initial moisture content was measured before running each experiment. Oven temperature of 130C° for 19h was used to determine the grain-moisture content. (Standards of the ASAE, 1996).

Experiment Design

Wide ranges of grain-storage temperature were used which are 4, 15, 25, and 40C°. Grain-moisture content levels were 15, 18, 21, and 24%. Mechanical damage levels were 0, 15, and 30%. Levels of damage were obtained by using Breakage Tester. The AST for below and in between these levels of storage-temperature, grain- moisture content, and mechanical damage can be predicted by equations. Three replications in each of the above levels were used. The total treatments were 144. The work was divided into four experiments. The first experiment used one level of moisture content which is 24% in all of storage room temperatures (4, 15, 25, and 40C°) and with all of the mechanical damage levels (0, 15, 30%). In each room of storage temperature, nine grain bins were used which are three levels of mechanical damage, and each level was replicated three times. Storage-grain temperature was measured by electronic device. Its probe was added at the inlet air passing to grain bins. The second experiment used 21% grain-moisture content with the other levels of grain-storage temperature and mechanical damage. The third experiment used 18% grain-moisture content with the other levels of grain-storage temperature and mechanical damage. The last experiment (No.4) used 15% grain-moisture content with the other levels of grain-storage temperature and mechanical damage.

Carbon Dioxide Production

The carbon dioxide absorption technique was used to measure the carbon dioxide production of the wheat samples. The experiment set-up used here was similar to those of AL-Yahya et al.(1993), Friday et al.(1989), Fernandez et al.(1985), and Steele et al. (1969). In each of the storage room temperature and grain-moisture content, nine complete carbon dioxide absorption systems were used. Aeration air came from a compressor installed outside the building. The system (**Fig.1**) includes the following components:

Carbon Dioxide Removal

Carbon dioxide in the incoming air was removed by bubbling the air stream through a 25% potassium hydroxide solution in a Drechel gas-washing bottle. Al-Yahya (1991) used gas chromatography technique to verify a complete removal of CO_2 after passing through the potassium hydroxide solution. According to the finding of Al-Yahya, the potassium-hydroxide solution was changed every three to four days.

Humidification

The relative humidity of the air stream was controlled by bubbling the air stream through two 250-ml Drechel gas-washing bottles in series. The first bottle was filled with water and the second with a saturated salt solution. The salt solution conditioned the air to the proper relative humidity. The grain moisture content was controlled by using these different solutions. The selection of each salt solution to control grain-moisture content was based on the equilibrium relationships reported by Wexler and Hasegawa (1954). Measuring relative humidity of air passing to the storage bin was checked daily by electronic meter.

Sample Storage and Aeration

The sample storage and aeration component consisted of a 55-cm long and 6 cm internal diameter hard plastic tube. A depth of 5 cm of fiberglass was used at the bottom of the sample storage as permeable floor. Air passing through the storage unit was controlled by both of a manifold air-distribution unit and a needle valve. Air was monitored by Matheson Model PM-1022 Acrylic Purge Flowmeters. Al-Yahya (1991) calibrated this flowmeter by Gilmont No. 12 flowmeter. Airflow rates were set at 0.45 m^3/mint of wheat throughout storage. The system was checked for air leaks at intervals of approximately 6 h.

Water Absorption

The production of water and CO_2 are results of grain and microorganism respirations. These two components will combine with air passing through the storage unit. In the experiment, two drying agents were used to absorb water vapor. The first agent was a 1:1 mixture of 8-mesh drierite anhydrous $CaSo_4$ and 8-mesh indicating drierite (97% $CaSo_4$ and 3% CoC_{l2}). The first agent was placed in a plastic tube 40 cm long and 2.45 cm in diameter. The advantage of this agent is that it changes color from white-blue to pink when it absorbs water vapor. An air stream was then passed through the second agent, magnesium percholorate ($Mg[ClO_4]_2$), which was placed in a plastic tube 40 cm long and 2.45 cm in diameter. The second drying agent was used only to ascertain whether any fraction of water vapor passing through the first agent had not been trapped. Because the second drying agent did not change color when it absorbed water, 5.08 cm of the first drying agent was placed at the bottom of the second drying agent to control completely the absorption of water.

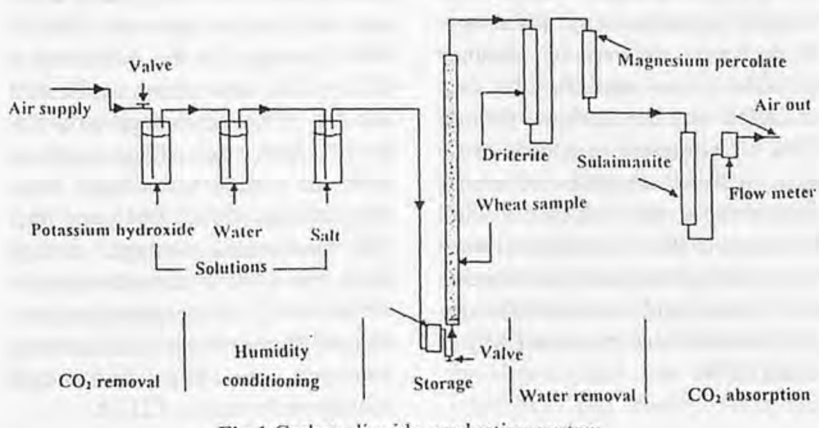

Fig.1 Carbon dioxide production system.

Carbon Dioxide Absorption

Production of water was absorbed in the previous agents and CO_2 remained. In the experiment, Al-Yahya agent was used to absorb CO_2. This agent was developed by Al-Yahya (1991). The process of absorption of CO_2 was as follows: As mentioned earlier, CO_2 and water are the results of grain and microorganism respirations. In the previous stage of the experiment, water was completely absorbed and CO_2 remained. The accumulation of CO_2 was absorbed in a plastic tube 30 cm long and 1.5 cm in diameter. This tube contained the CO_2 absorbing agent Al-Yahya, a mixture of vermiculite and potassium hydroxide solution. This agent was at the top of the tube with depth of 15-cm. Also, in the middle of the tube, magnesium perchlorate was put with depth of 5 cm and at the bottom of the tube, depth of 5 cm of drierite was added. These two agents (in the middle and bottom) were used to absorb any water liberated from the Al-Yahya agent; according to the following chemical equation

$$2KOH + CO_2 > K_2CO_3 + H_2O \quad (3)$$

The water liberated due to the chemical reaction in this equation had to be included in the net weight-gain of carbon dioxide accumulation. Reading of CO_2 weight were taken every 12-48 hours depending on the used moisture content. Reading were taken

Table 2. Storage Time in Hours for Wheat of 24% Moisture Content Stored at Different Levels of Grain Temperatures and Mechanical Damage

Grain Temperature (C°)	Mechanical Damage (%)	Dry Matter Loss (%)			
		0.25	0.50	0.75	1.00
	0	996	1380	1644	1896
4	15	684	1116	1332	1476
	30	540	876	1092	1224
	0	372	612	750	864
15	15	288	420	576	696
	30	180	348	480	600
	0	192	312	384	>384A
25	15	96	180	240	312
	30	84	144	192	252
	0	96	168	216	240
40	15	60	108	132	156
	30	48	96	120	144

A: Experiment was terminated at 384 hr.

Table 3. Storage Time in Hours for Wheat of 21% Moisture Content Stored at Different Levels of Grain Temperatures and Mechanical Damage

Grain Temperature (C°)	Mechanical Damage (%)	Dry Matter Loss (%)			
		0.25	0.50	0.75	1.00
	0	1176	1776	2136	2400
4	15	936	1416	1752	2016
	30	768	1248	1584	1848
	0	600	960	1200	1368
15	15	456	768	984	1152
	30	336	600	792	936
	0	432	672	840	960
25	15	264	456	624	720
	30	216	408	552	672
	0	288	528	>600A	>600A
40	15	168	360	504	>600A
	30	120	240	360	480

A: Experiment was terminated at 600 hr.

every 12 hours during the experiments of 21 and 24% MC while 24 hour was used with 18% MC experiments and 48 hours was used with the experiment 15% MC. The Al-Yahya agent columns were hung after being saturated with CO_2, their color changing from dark to light gray upon absorption of CO_2. Any change in color of the drierite material in the bottom will indicate that this column is saturated and should be changed very soon. After each experiment, the whole system was disassembled and cleaned. Cleaning was necessary, especially for the grain column; if columns were not thoroughly cleaned using the same column for the next experiment would contaminate the new grain. Cleaning steps were taken in the following order: warm water, soap, warm water, and cooled distilled water.

Statistical Analysis

A statistical analysis was done using the SAS statistical package on the results of all experiments, a randomized complete block design which included 48 treatment combinations consisting of four levels of grain-moisture content, four levels grain-temperature, and three levels of grain-mechanical damage. A two-way analysis of variance (ANOVA) was used for the data collected in the carbon dioxide tests. Orthogonal contrasts were used to make comparisons among treatment means (Snedecor and Cochran, 1989). Comparisons were made for moisture levels, temperature levels, and mechanical damage levels for the dry-matter loss to reach 0.5%.

Results and Discussion

Since the work was divided into four experiments, four different results will then be presented.

Experiment No 1.

Table 2 shows the storage time (in hours) of wheat at 24% grain-moisture content stored at 4, 15, 25, and 40C° and three levels of mechanical damage (0, 15, and 30%) in each storage room temperature. From **Table 2**, it will be seen that storage time was prolonged due to decreasing levels of grain-storage temperature, grain-moisture content, and mechanical damage. If 0.5% DML is considered to be the changing quality grade of wheat from grade No.1 to grade No.2, then the wheat will remain in the store only for 168, 108, and 96 h when it has 0, 15, 30% mechanical damage, respectively, and stored at 40C°. But when the samples stored at lower temperature as in 15C° then the storage time to go from wheat grade No.1 to grade No. 2 was increased. At 0, 15, and 30% mechanical damages, storage times were 612, 420, and 384 h., respectively. The same thing happened when storing wheat at more lower temperatures. The effect of mechanical damage can be easily seen. As an example, at 4C° and 1.0% DML, storage time was 1896 h when the sample has 0% mechanical damage. But when the same sample has 30% mechanical damage the storage time was 1244 h which means that the difference is 672 h. The same thing can be said for the effect of storage temperature. Change of storage temperature did change the storage time. For example, At 0.5 DML and with 0% mechanical damage, storage time was 1380 h when the sample stored at 4C°. But, when the same sample stored at 40C°, the storage time was only 168 h which means that the difference is 1212 h.

Table 4. Storage Time in Hours for Wheat of 18% Moisture Content Stored at Different Levels of Grain Temperatures and Mechanical Damage

Grain Temperature (C°)	Mechanical Damage (%)	Dry Matter Loss (%)			
		0.25	0.50	0.75	1.00
	0	864	1680	3744	2688
4	15	720	1440	2832	2592
	30	624	1296	2592	2400
	0	960	1872	2544	3024
15	15	816	1536	2160	2688
	30	624	1368	1824	2304
	0	696	1056	1872	2256
25	15	526	984	1488	1848
	30	480	792	1368	1728
	0	408	648	1104	1344
40	15	336	576	936	1176
	30	288	792	816	1056

Table 5. Storage Time in Hours for Wheat of 15% Moisture Content Stored at Different Levels of Grain Temperatures and Mechanical Damage

Grain Temperature (C°)	Mechanical Damage (%)	Dry Matter Loss (%)			
		0.25	0.50	0.75	1.00
	0	2248	3936	4944	>5424[1]
4	15	1584	3880	3840	4656
	30	1344	2496	3360	4128
	0	1536	2688	3504	4224
15	15	1152	2112	2832	3504
	30	1104	1968	2688	3264
	0	1104	2112	2928	3611
25	15	912	1824	2544	3264
	30	768	1536	2208	2832
	0	864	1728	2400	>2688[2]
40	15	720	1440	2016	2640
	30	672	1296	1872	2400

1: Experiment was terminated at 5424 hr.
2: Experiment was terminated at 2688 hr.

Experiment No.2.

Table 3 shows the storage time of 21% moisture content of wheat stored at 4, 15, 25, and 40C° and three levels of mechanical damage. What was mentioned in experiment No.1 can be repeated here. The trend was about the same. Storing the wheat at higher grain-storage temperature and higher mechanical damage reduced the storage time or increased the deterioration rate. For example, at 0.5% DML, increasing the level of mechanical damage from 0% to 30% when the sample stored at 15C° reduced the storage time to 360 h. Also, going down from storing the wheat at 40C° to 4C° when the mechanical damage was 15% for both samples increased the storage time to 768 h.

Experiment No.3.

Table 4 shows the storage time in hours of wheat at 18% grain-moisture content stored at 4, 15, 25, and 40C° and three levels of mechanical damage (0, 15, and 30%) in each storage room temperature. Again, in this experiment, the trend was about the same as in experiment No.1 and experiment No. 2. Storing the wheat at lower temperature and lower mechanical damage caused reduction in deterioration rate. Comparing storing wheat at grain-storage temperature of 4C° to grain-storage temperature of 40C° when the mechanical damage was 30% increased the deterioration rate more than three times. And when comparing storing the wheat at mechanical damage of 0% to 30% if the sample stored at 25C°, the deterioration rate is by about 1.5 times. The above comparison proved that the effect of grain-storage temperature is more than the effect of mechanical damage in regard of storage time.

Experiment No.4.

Table 5 shows the storage time in hours of wheat at 15% grain-moisture content stored at 4, 15, 25, and 40C° and three levels of mechanical damage (0, 15, and 30%) in each storage room temperature. The findings in this experiment are the same as in the previous experiments. Decreasing the grain-storage temperature played a major role in increasing the storage time of wheat. At 30% mechanical damage level, the wheat grade will be changed from No.1 to No.2 after 1296 h. However, if stored at 40C° while the same sample will remain at grade No.1 up to 2496 h. if stored at 4C°. The same thing can be said for the effect of mechanical damage.

Combination of Experiments

Table 6 shows the effect of all of the studied factors which are moisture content, grain storage temperature, and mechanical damage. It shows the storage time in days at 0.5% DML when the wheat samples stored at four levels of moisture content, four levels of grain-storage temperature, and three levels of mechanical damage. In **Table 6** when the moisture level, grain-storage temperature, and mechanical damage were increased, the storage times were reduced. At 4C° grain-storage temperature and 15% mechanical damage, the storage time of 24% wheat moisture content was 16.5 days while the storage time of 15% wheat moisture content with the same condition was 120 days. Changing the moisture content level from 24% to 15% increased the storage time about three times. With the increasing of grain-storage temperature, the difference in storage time is increased. For example, if the wheat was stored at 40C° and 15% mechanical damage, the storage

Table 6. The Allowable Storage Time for Stored Wheat in Days

Storage Grain-Temperature (C°)	Mechanical Damage (%)	Grain-Moisture Content (%)			
		15	18	21	24
	0	164	124	74	57.5
4	15	120	88	59	46.5
	30	104	84	52	36.5
	0	112	78	40	25.5
15	15	88	64	32	17.5
	30	82	54	25	14.5
	0	88	57	28	13
25	15	76	44	19	7.5
	30	64	41	17	6
	0	72	33	22	7
40	15	60	27	15	4.5
	30	54	24	10	4

Table 7. Estimated Storage Time Values of Comparisons among Treatment Means at 0.5% DML

Contrasts		Result	Estimate, days
Temp. 4	vs. Temp. 15	Significant	22.25
Temp. 4	vs. Temp. 25	Significant	36.61
Temp. 4	vs. Temp. 40	Significant	47.26
Temp. 15	vs. Temp. 25	Significant	14.36
Temp.15	vs. Temp. 40	Significant	25.01
Temp. 25	vs. Temp. 40	Significant	10.65
Damage 0	vs. Damage 15	Significant	12.64
Damage 0	vs. Damage 30	Significant	18.79
Damage 15	vs. Damage 30	Significant	6.17
Moisture 15	vs. Moisture 18	Significant	39.64
Moisture 15	vs. Moisture 21	Significant	57.56
Moisture 15	vs. Moisture 24	Significant	70.26
Moisture 18	vs. Moisture 21	Significant	17.92
Moisture 18	vs. Moisture 24	Significant	30.63
Moisture 21	vs. Moisture 24	Significant	12.71

Table 8. Equations of Predicting AST in Days Versus Grain-Moisture Content, Wet Basis (MC,%)

Temp., C	Damage, %	Equation	R^2
4	0	345.05-12.32MC	0.98
4	15	240.55-8.32MC	0.98
4	30	221.55-7.82MC	0.98
15	0	257.76-9.95MC	0.97
15	15	208.65-8.12MC	0.98
15	30	194.35-7.72MC	0.94
25	0	211.6-8.47MC	0.98
25	15	186.6-7.683MC	0.96
25	30	160.7-6.6MC	0.98
40	0	167.4-6.87MC	0.92
40	15	142.65-5.95MC	0.92
40	30	129.6-5.47MC	0.90

time will be 4.5 days at 24% MC while it is 60 day at 15% MC. The difference in this case will be 13 times.

Statistical Results

Statistical analysis results in the form of estimate contrasts among treatment means are presented in the **Table 7** for times to reach 0.5% DML. From **Table 7**, it is shown that all of the statistical results between levels of temperature, moisture, and mechanical damage are found to have significant differences.

Regression and Correlation

The actual means of all of the experiments data for temperature, moisture, and mechanical damage levels were put in form of equations. From these equations, AST can be predicted under any storage conditions of temperature, moisture, and mechanical damage. These equations are presented in **Table 8**, **9**, and **10**. To show the strength of the temperature, moisture, and mechanical damage versus storage time, R^2 are shown in the same table in front of each equation.

Gurjar results compared with those of the study. Gurjar (1917) measured CO_2 only per 24 h per 100 gm dry matter at different storage temperatures and moistures. He put the samples in glass container. CO_2 was measured by Barium hydroxide [Ba $(OH)_2$] solution. This study is different from the current study. Gurjar study was done for a very short time which is 24 hours while in this study the samples were left until the actual storage time was achieved. In the case of the Gurjar study, the storage time will not be the actual but it will be predicted. Gurjar also used volumetric method for measuring CO_2 while in this study, a quantitative method is used. Although there are differences between these studies, some comparisons can be extracted. **Table 11** shows the comparison of the results at some storage conditions.

Conclusion

As expected, the AST for low grain-temperature, low grain-moisture content, and low grain-mechanical damage was longer than in the high grain-temperature, high grain-moisture content, and high grain-mechanical damage.

REFERENCES

Al-Yahya, S.A., 1991. Fungicide treatment of high-moisture corn. Ph.D. Thesis, ISU Library, Ames, Iowa, U.S.A.

Al-Yahya, S.A., Bern, C. J., Misra M.K., and Bailey T. 1993. Carbon

Table 9. Equations of Predicting AST in Days Versus Grain-temperature (C°)

Moist., C	Damage, %	Equation	R^2
15	0	161.05-2.48(T)	0.89
15	15	119.62-1.6(T)	0.93
15	30	105.26-1.29(T)	0.94
18	0	124.48-2.45(T)	0.94
18	15	91.38-1.7(T)	0.97
18	30	84.61-1.61(T)	0.94
21	0	69.95-1.38(T)	0.82
21	15	56.2-1.2(T)	0.83
21	30	49.21-1.11(T)	0.85
24	0	54.03-1.35(T)	0.83
24	15	42.33-1.11(T)	0.78
24	30	33.42-0.87(T)	0.80

Table 10. Equations of Predicting AST in Days Versus Grain-Mechanical Damage (%)

Moist., %	Temp., C°	Equation	R^2
15	4	159.33-0.2(D)	0.93
15	15	109-(D)	0.89
15	25	88-0.8(D)	1.00
15	40	71-0.6(D)	0.96
18	4	118.67-1.33(D)	0.82
18	15	77.33-0.8(D)	0.99
18	25	55.33-0.53(D)	0.88
18	40	32.5-0.3(D)	0.96
21	4	72.67-0.73(D)	0.96
21	15	39.83-0.5(D)	0.99
21	25	26.83-0.36(D)	0.88
21	40	21.66-0.4(D)	0.99
24	4	57.33-0.7(D)	0.99
24	15	24.67-0.36(D)	0.94
24	25	12.33-0.23(D)	0.90
24	40	6.66-0.1(D)	0.87

Table 11. Comparisons between Gurjar Study and the Current Study

Gurjar study			Current study		
Temp.,C°	Moist.,%	Mg CO_2/24h/100gm dm	Temp.,C°	Mois.,%	Mg CO_2/24h/100gm dm
37.8	15	1.20	40	15	1.02
37.8	16	2.72	40	18	2.23
4	15	0.24	4	15	0.45
25	15	0.45	25	15	0.83
35	15	1.30	35	15	1.02

dioxide evolution of fungicide-treated high-moisture corn. Trans. of ASAE 36(5): 1417-1422.

Aljinovic, S., C.J. Bern , P. N. Dugba, and M.K Misra. 1995. Carbon dioxide evolution from high-moisture shelled corn treated with iprodine. Journal of food protection, 58(6): 673-677.

ASAE Standards. S352.2 1996. Moisture measurement-unground grain and seeds. St. Joseph. MI: ASAE 497.

Baily, C.H. and Gurjar, A.M. 1918. Respiration of stored wheat. Journal of agricultural research No. 11 Vol XII, 685-713.

Fawole, L. O. 1969. Deterioration of high moisture corn at Iowa temperatures as measured by CO_2 production. M.S. thesis Parks Library, Iowa State University, Ames.

Fernandez, A., R. L. Stroshine and J. Tuite. 1985. Mold growth and carbon dioxide production during storage of high-moisture corn. Cereal Chem. 62 (2): 137 - 144.

Friday, D. C., J. Tuite and R. Stroshine. 1989. Effect of hybrid and physical damage on mold development and carbon dioxide production during storage of high moisture shelled corn. Cereal Chem. 66 (4): 422 - 426.

Gurjar, A. M. 1917. The adaptation of Truog's method for the determination of carbon dioxid to plant respiration studies. In Plant World, Vol. 20, No. 9, 299-293.

Saul, R.A., and E.F. Lind. 1958. Maximum time for safe drying of grain with unheated air. Trans. Of the ASAE 1:29-33.

Saul. R.A. and J.L. Steele. 1966. Why damaged shelled corn cost more to dry. Ag. Eng. 47: 326-329.

Seitz, L. M., D. B. Sauer, H. E. Mohr amd D. F. Aldis. 1982. Fungi growth and drying matter during bin storage of high-moisture corn. Cereal Chem: 59 (1): 9 - 14.

Snedecor, G. W. and W. G. Cochran. 1989. Statistical Methods, 8th Ed. mes: Iowa State University Press.

Steele, J. L. 1967. Deterioration of damaged shelled corn as measured by CO_2 production. Ph D. Thesis, ISU Library, Ames, Iowa, U.S.A.

Steele, J. L. R.A., Saul and W.V. Hukill, 1969. Deterioration of shelled corn as measured by Co_2 production. Trans. ASAE 12(5): 685-689.

Thompson, T.L., 1972. Temporary storage of high moisture corn using continuous aeration. Trans. ASAE 15: 333-337.

Wexler, A. and S. Hasegawa. 1954. Relative humidity- temperature relation ships of some saturated salt solutions in the temperature range 0 to 50 C°. Journal of Research of the National Bureau of standards. vol. 53, No1. ■■

Standards Benefit Developing Irrigation Markets

by

Kenneth H. Solomon
Professor and Head
Bio Resource and Agricultural Engineering Department
California Polytechnic State University (Cal Poly), San Luis Obispo, CA 93407
USA
E-mail: ksolomon@calpoly.edu

Allen R. Dedrick
Associate Deputy Administrator for Natural Resources and Sustainable Agricultural Systems
US Department of Agriculture, Agricultural Research Service, National Program Staff
Rm. 134, Bldg. 005, BARC-West, Beltsville, MD 20705 USA
E-mail: ard@ars.usda.gov

Abstract

Standards are important tools for all members of the irrigation community. A complete irrigation standards program includes not only the standards documents, but also standards development procedures, testing and enforcement mechanisms for standards compliance, and vehicles for communication with all interested parties. Standards benefit the irrigation community by: facilitating comparable product information; setting performance and safety minimums; ensuring compatible connections; protecting consumers and suppliers alike from substandard equipment; and setting consistent procedures for field evaluation and acceptance. Benefits of special significance in developing irrigation markets include: assisting local manufacturers to improve and maintain quality; providing consumers with reliable and comparable technical information on products, systems, and practices; aiding educational efforts; and facilitating technology transfer. Irrigation standards in developing markets encourage the adoption of high efficiency technologies because product failures are minimized. Case study results from Egypt support these observations. Many irrigation markets throughout Asia, Africa and Latin America, like Egypt, depend on a combination of locally produced and imported technologies, suggesting that the principles presented here may have widespread application.

Introduction

Irrigation equipment standards are important tools in the selection, design, purchase, installation, operation and evaluation of irrigation systems and equipment. Standards can play a particularly important role in developing irrigation markets world-wide. Often associated with such markets is the potential for improvements in irrigation practice, water management, resource utilization and crop production. Standards can make significant contributions toward achieving this potential, and in the process stimulate trade by increasing the market for advanced technologies and by making the market more trade-friendly. This is an important consideration for markets dependent on a combination of locally produced and imported equipment and technologies, such as many in Asia, Africa and Latin America. Case study results from Egypt, presented below, offer a specific example of these general principles.

Before discussing the importance and benefits of irrigation equipment standards in developing markets are discussed, the various elements of a comprehensive standards program for irrigation are described. A complete irrigation standards program includes not only standards documents, but also standards development procedures, testing and enforcement mechanisms for standards compliance, and vehicles for communication with all interested parties. A successful standards program necessarily combines both international and national elements.

Standards

The term *standards* is often interpreted narrowly, meaning only the documents called standards. However, such documents alone are insufficient to realize the full benefits of standards in developing irrigation markets. Mechanisms and institutions facilitating participation in the full range of standards related activities must exist or be developed if the maximum benefits are to be achieved. More properly, then, *standards* refers to the functions, procedures and institutions of the entire standardization process, as well as to standards documents themselves: *standards* implies a complete standards program.

Standards in the broad sense of a *standards program*, is understood to include:

- Documents;
- Procedures for standards development, review and update;
- Compliance mechanisms;
- Testing, evaluation and inspection of products, assemblies and systems in both laboratory and the field.

- Communication and education of interested parties;
  ~ Feedback to suppliers; and
  ~ Feedback to consumers.

Documents

There are generally four types of irrigation standards documents. (1) Irrigation product standards specify requirements for individual products, such as general requirements for construction, materials, product marking and supporting literature, and key performance indicators; (2) Procedural standards establish uniform methods for testing and evaluation of products and systems. Gages, fixtures, methods, accuracy requirements, data analysis and reporting requirements may be specified; (3) Technology standards specify an approved or recommended irrigation practice, such as a procedure for design, installation; operation or evaluation of a system; (4) Information standards specify technical data, mathematical relationships [equations, tables, graphs or nomograms], data collection forms, definitions and classification schemes. Combination documents include features of more than one type of standard.

Standardization Procedures

International standards for irrigation equipment and systems are developed by the International Organization for Standardization (ISO) Technical Committee 23, Subcommittee 18 (ISO/TC23/SC18), which is responsible for irrigation and drainage standards within ISO. The American Society of Agricultural Engineers (ASAE) is an analogous organization within the USA developing standards in the field of agricultural engineering. Within the area of irrigation, ASAE coordinates its efforts with the Irrigation Association, a trade organization for the irrigation industry. Solomon and Dedrick (1995) summarize the procedures used by both ISO[1] and ASAE[2] to develop national and international standards for irrigation equipment, systems and practices.

It is recommended that any country with a significant interest in irrigation standards consider becoming a member of ISO/TC23/SC18. This will enable national officials and irrigation experts to remain current, influence SC18 work schedule and priorities, to participate in early drafts of developing standards. Unique national conditions, practices or constraints may be presented for consideration during SC18 deliberations.

Standards Compliance

Standards compliance mechanisms vary with country. Within the United States, irrigation standards are generally voluntary (except in the areas of human health and safety). Manufacturers are not required to make products according to standards, nor to submit products for testing to establish compliance. The marketplace acts as the compliance enforcement mechanism, assuming knowledgeable consumers will not buy substandard goods.

In some countries, standards compliance is compulsory. Products must be submitted for test, and proof of compliance with applicable standards must be obtained before commercial sale of the products is permitted. This applies to both locally manufactured and imported products.

A third, less stringent approach is to require only that products be submitted for testing, with the results made public. This ensures that reliable product information is available, and consumers, thus informed, may judge for themselves whether a given product will meet their needs at an acceptable price.

Product Testing

A local, independent (i.e., not connected with any commercial interest) means to test and evaluate locally made or imported products is important. Reports and certifications from qualified laboratories in other countries are helpful, and can meet a part of the information needs of a developing market. But these outside information sources are usually too slow and too inflexible to provide the feedback required by a developing market (see paragraphs below on *Communication*).

A local irrigation product testing capability serves the developing market in many ways. Local irrigation manufacturers can use test results to guide the development of new and revised products, to monitor the quality of their manufacturing process, and to form the basis for catalogs and other technical literature to support the effective application of their products. Foreign suppliers are prevented from "dumping" substandard products into the market, a concern in some areas (e.g., Zimbabwe - see Solomon and Zoldoske, 1994). Suppliers [including manufacturers, distributors and dealers] can use test results to show compliance of their products to applicable standards and purchaser specifications.

Irrigation advisors [e.g., designers, consultants, agricultural extension advisors] can use product performance data beyond typically published catalog data to guide product comparison, selection and system design. Examples of useful information not usually published by the manufacturer in irrigation product literature include the uni-

[1] A complete specification of the procedures used by SC18 can be found in the three volume ISO Directives for standards development issued by the ISO Central Secretariat in Geneva, Switzerland.

[2] Procedures for developing standards within ASAE can be found in Standardization Procedures (ASAE, 1998, pages 2-10). For further information, contact ASAE, 2950 Niles Road, St. Joseph, Michigan 49085 USA. Telephone: 616-429-0300. FAX: 616-429-3852. E-mail: hq@asae.org.

formity of sprinklers under different spacing and wind conditions, and the coefficient of manufacturing variation for microirrigation emitters.

End users of irrigation equipment can use test results to guide product comparison and selection, to verify that products delivered actually perform as designed, and to trouble-shoot problems which may develop after installation. In California, USA, purchase contracts for micro-irrigation equipment frequently require that products delivered to the purchaser be tested at an independent laboratory to verify such items as emitter discharge rate at the design pressure and coefficient of manufacturing variation (Zoldoske, 1995). All parties involved in the purchase are supportive of this protection: farmers are assured that the products delivered perform as desired; designers are assured that the products delivered do satisfy the hydraulic assumptions upon which they have based their design; and manufacturers and dealers are relieved to know that potential problems will be caught prior to installation, since post-installation field fixes are notoriously expensive.

Laboratory testing to support trouble-shooting of equipment problems in operating irrigation systems is a very valuable service to irrigators. It is often helpful to duplicate in the laboratory those conditions and problems encountered in the field. Such testing usually requires non-standard test fixtures and procedures, as field/problem conditions are often different from those specified for standard test procedures. Hypothesized failure mechanisms and proposed problem solutions should be tested and verified before they are implemented in the field.

Some irrigation assemblies or systems are too large for laboratory testing. Field evaluation may be required for acceptance by the purchaser. In such cases, the field evaluation should be conducted under standard conditions, or as specified in the purchase agreement. An example of a standard for such an evaluation is ISO 11545 Agricultural Irrigation Equipment - Centre-Pivot and Moving Lateral Irrigation Machines with Sprayer or Sprinkler Nozzles - Determination of Uniformity of Water Distribution (ISO, 1995). In other cases, the evaluation is done to appraise the performance and operation of the system as it stands. The results may guide system renovation or upgrade, suggest improvements in system operation and management, or aid in trouble-shooting problems with the system.

Field inspections and tests may be required periodically to verify that equipment remains in working order. This can be particularly important where issues of human health and safety are concerned. An example of such a standard is ASAE EP 409.1 Safety Devices for Chemigation (ASAE, 1998, pages 880-882). Specifications for products or assemblies may include features to facilitate field inspection and evaluation. For example, chemigation valves and backflow prevention assemblies to prevent irrigation backflow should incorporate test ports on each side of the check valve to facilitate field tests of opening pressure and backflow leakage (Solomon and Zoldoske, 1995).

Communication

A key role of any local testing laboratory is to provide feedback to irrigation suppliers, including manufacturers, irrigation distributors, dealers and installers. Standards and tests for compliance are very important to suppliers. Testing laboratory and field evaluation personnel must be able to respond quickly and flexibly to irrigation suppliers in order to facilitate timely application of test results. Product development, manufacturing process control, irrigation equipment selection and system design all require a quick response if test results are to be used effectively. The flexibility to work with clients and develop specialized, problem-specific test fixtures and procedures will greatly aid product development and trouble-shooting in the field. Distant test laboratories providing only results from standard tests rarely can meet these needs.

Of course, feedback to irrigation consumers, and those that influence, serve or advise consumers is also a major function of test laboratories. Farmers, system designers and operators, equipment specifiers and irrigation or water management extension advisors all need to have timely access to both standard and specialized test results. The unrelenting march of the cropping calendar will require that decisions be made and implemented, whether informed or not. And, uninformed decisions are likely to be sub-optimal ones.

Education

Irrigation standards, equipment testing laboratory and field evaluation personnel should do more for irrigation suppliers and consumers than simply inform and report. Particularly in developing irrigation markets, they should help educate as well. Reports, newsletters, field days, seminars and workshops are educational vehicles that can greatly enhance the contributions of a standards program in a developing market.

The very existence of equipment standards and testing laboratories raises general awareness of equipment related issues, which can be of special value in a developing market. In the absence of timely and reliable technical information, farmers tend to make equipment purchase decisions based primarily on cost. But the existence of equipment standards and testing laboratories makes farmers and irrigation advisors aware that product choices have performance as well as cost consequences, and that true economy is achieved only if these are considered together. Laboratory communications and education programs must make irrigation consumers aware that product information is available, explain how to obtain it, and present it in a comprehensible way. The local irrigation testing laboratory is in a unique position to give irrigation consumers the tools they need to make performance/cost comparisons, and hence to make better purchase decisions. Laboratories equipped to test irrigation products may also be able to devise special demonstration configurations to illustrate proper installation, adjustment, etc., and perhaps the consequences of improper installation or operation as well.

Product and technology standards can be used to educate consumers about the effective use of irrigation products. By specifying performance indicators, recommended irrigation practices, and guidelines for installation and operation, these documents present much of the information necessary for effective equipment use. Thus, standards programs play a role in technology transfer and the adoption of improved technologies.

Both International and National Elements Necessary

As the foregoing sections illustrate, any successful irrigation standards program must incorporate both international and national elements. Standards for minimum product performance and testing methods should be international, while the standards development, field testing and feedback functions cannot be successful without involvement at the national level. Fussing over differences between national and international standards *documents* only wastes energy better spent on local participation in the international standards *program*.

Standards in Developing Irrigation Markets

The importance and general benefits of irrigation standards and standardization are reviewed elsewhere (Solomon and Dedrick,1994, 1995; ASAE, 1998). These general benefits apply as well to developing as to developed markets. However, the contributions of an irrigation standards program can be of special significance in developing irrigation markets. These contributions include ensuring product quality, providing assistance to irrigation suppliers (local or foreign) and consumers, aiding efforts at education, and facilitating technology transfer. Trade is enhanced by assisting those participating in the developing market.

Product Quality

A standards program helps ensure quality by both identifying problems and providing tools to improve quality. Standards, testing and compliance mechanisms keep the market free of substandard or low quality goods. Quality audit testing of products delivered to farms can identify problems before installation. Frequent and timely feedback from testing laboratories enables local manufacturers to improve quality. Standards provide the benchmark and impetus to improve quality; testing and feedback help to monitor quality and aid manufacturing process control.

Assist Local Irrigation Suppliers

Standards provide for compatible connections for irrigation equipment from different sources, and a reduction in the variety of component sizes needed to serve the irrigation industry. Suppliers bidding to standards-based specifications are assured that they will not have to bid against substandard equipment which does not meet even minimum criteria. Pre-installation testing of products identifies problems before costly in-field fixes are required.

Equipment testing helps local manufacturers with product development. Independent test laboratories free individual local manufacturers from each building their own facilities. This prevents expensive duplication ill afforded in developing markets, and removes a potential entry barrier to smaller manufacturers. Information from testing laboratories identify quality problems and facilitate quality improvement efforts.

Assist Local Irrigation Consumers

Standards provide the basis for a common understanding of performance issues, and ensure that irrigation product information is comparable. Connection compatibility is ensured, and standardized component sizes result in improved availability and economy for irrigation products. Standards, testing and compliance mechanisms screen out low quality products. Using standards to specify or pre-qualify irrigation equipment that will be considered for purchase assures consumers that equipment purchased satisfies minimum performance and safety criteria. Standards for field evaluation and pre-installation testing ease consumer acceptance worries. They also help farmers maintain irrigation systems and improve irrigation practices. Special, problem-specific testing aids trouble-shooting of irrigation problems.

Education

Standards programs increase the general awareness and knowledge of equipment related factors in irrigation practice, and encourage the market to consider performance as well as cost. Performance information on products and practices is made available to advisors and farmers. Field evaluation standards guide agricultural advisor recommendations to farmers. Irrigation laboratories can provide facilities for training agricultural advisors and farmers.

Facilitate Technology Transfer

Education, consumer awareness of performance issues, knowledge gained from irrigation practice standards, and testing and field evaluation will all help with the transfer of advanced irrigation technologies into the developing market place. But the greatest aid to technology transfer is the ability of a standards program to reduce product and quality related failures. Such failures affect more than just the areas irrigated by the failed projects. Far more significant is that these failures generate a fear of the new technology that prevents other farmers from wanting to try it. Adoption rates are greatly reduced, and widespread implementation of the new technology can be postponed substantially. For example, failures due to emitter, hose and filter problems slowed the early adoption of micro-irrigation in the United States, Australia, South Africa, Zimbabwe, India and other areas (Zoldoske, 1995). By minimizing product failures and related fears, a complete standards program maximizes adoption rates and supports the farm advising infrastructure that will help farmers to succeed with the new technology.

Irrigation Standards Build Trade

Standardized market requirements, fewer component sizes, comparable product information, a common understanding of performance, uniformity in product testing and acceptance, and minimum performance criteria for product specification are all trade enhancing derivatives of a comprehensive standards program. But standards impact on the marketplace itself provide the greatest boost for trade.

Since standards accelerate adoption of advanced irrigation technologies, they increase total market size. Increased markets stimulate development of local suppliers for "commodity" products such as pipe, hose, fittings, valves, which can reduce system costs (at the least, transport and import costs for commodity items are eliminated), and further stimulate the market. Increased markets and the availability of quality, locally produced commodity products generates an increased market demand for advanced, high-technology products and services that might be supplied from developed irrigation markets. Examples include turn-key pumping stations, system monitoring and control equipment, specialty valves, consulting, design, installation and management services. Standards programs educate consumers about important product selection criteria. Trade with developing irrigation markets is usually increased when consumers can be convinced to look beyond price and consider performance as well.

Egypt: A Case Study

The results of field studies in Egypt illustrate the practical benefits of standards in developing irrigation markets. During July 1994, interviews with government officials, academics, researchers, farm advisors and farmers were conducted in lower Egypt from Cairo to the Nile Delta (Solomon, 1994). This inquiry identified wide spread and general support among the local irrigation community for irrigation standards and the development of a complete standards program. Most of the benefits just presented were cited by local irrigationists during the course of these interviews.

The Developing Egyptian Irrigation Market

Dr. A. M. El-Gindy (1994) identified some circumstances in the Egyptian irrigation marketplace that underscore the need for irrigation standards:

- To maximize effective use of available water supplies, the Egyptian government has decreed that only pressurized irrigation systems shall be used to develop newly irrigated Nile Delta areas.
- Government resettlement programs are placing individuals without previous farming experience onto new development projects.
- These new development projects involve lands with different soil, climate and water quality conditions than traditional Nile Valley farming. New agronomic technology packages, suitable for these difficult conditions, must be developed.
- A greatly expanded corps of farm advisors must be recruited and trained to assist the new farmers.
- Several local, small manufacturers of irrigation products have recently been established. They all lack facilities for extensive product testing and quality control.

Observations and Industry Objectives

Discussions with a leading Egyptian manufacturer of drip irrigation equipment suggest that quality is a major issue in the adoption of pressurized irrigation systems. Quality control procedures of local manufacturers are insufficient to consistently produce quality goods.

One manufacturer checks tubing quality primarily for uniformity of resin mix, percent carbon black, and stress crack resistance. This is done once for each batch of raw materials mixed. Emitter flow rates are checked in an approximate way a few times per shift. Other dripline parameters are checked visually. Samples are sent to Europe for more extensive testing once per month. But monthly quality testing is an inadequate quality control procedure for a plant producing 40,000 meters of dripline per day.

A second manufacturer producing a similar dripline also makes fittings, valves and other auxiliary equipment. They check their dripline production for proper flow rate once each day. They believe their quality is high, and that the quality of Egyptian made irrigation products generally is high. However, excessive blemishes along mold joint lines, knit-lines and other irregularities in the areas of injection ports were observed. These defects were greater than those typically observed in products from developed market suppliers, and in some cases could affect product performance (e.g., emitter clogging and/or flow rate, strength of valve opening wheels).

Other Egyptian manufacturers reportedly use even less stringent quality control procedures. Varying amounts of recycled plastics (with varying chemical properties) can be used in the production of drip hose. Because even careful recycling tends to incorporate sufficient contaminants to significantly degrade the physical properties of the pure resin material, this practice frequently leads to premature failure of the hose. Microirrigation in the United States suffered from this phenomenon during the mid 1970's to early 1980's. In areas where this practice, and the resulting failures, were common, the adoption of drip irrigation was drastically slowed.

One Egyptian industry representative said "A standards program and local testing laboratory are needed to help our industry upgrade its practices and products, and to guarantee that farmers receive the quality they require." Another offered unconditional support for an irrigation standards program and equipment testing laboratory, saying "We need this very badly." Both pointed out an additional benefit, that verification of standards compliance would enable Egyptian-made products to be exported and marketed more successfully in other Arab countries. The laboratory's verification of quality would be seen as an important, independent, third party confirmation of quality and performance. The comments of all those interviewed show that there is significant industry support for an irrigation standards program and testing laboratory in Egypt.

Governmental Objectives

Egyptian university irrigation experts and government agricultural agency representatives are looking for help from an irrigation standards program to minimize product and quality related failures in new irrigation systems, to avoid reduced rates of adoption of pressurized irrigation, and to train new agricultural advisors in the proper use of irrigation equipment.

Government officials seek at least one fully equipped irrigation equipment testing laboratory, able to respond to all testing needs. If resources allow, a second laboratory, equipped to do basic irrigation equipment testing would also be established. This laboratory would include "training" fixtures in addition to the necessary testing fixtures so that the proper installation, adjustment, operation and maintenance of equipment can be demonstrated. This capability is particularly important for such equipment items as filters, control systems and chemigation equipment, where the details of proper operation are both complex and vital to the success of the irrigation system. This second testing facility would also do specialized testing to aid the troubleshooting of irrigation system field problems.

The International Trade Connection

Circumstances in Egyptian guarantee a *potentially* large and developing irrigation market. The sale of pressurized irrigation systems in Egypt represents a major *potential* trade opportunity for high-technology irrigation products and services. However, the *actual* irrigation market will be largely dependent on adoption rates for these new technologies. An irrigation standards program, combining international norms with Egyptian application institutions, will enhance adoption rates for pressurized irrigation systems and increase the market for both locally produced and imported irrigation products. Imported goods will further benefit from a standards program that educates irrigation consumers and provides a fair basis for comparison and acceptance of product.

Summary and Conclusions

Irrigation equipment standards are important tools for all members of the irrigation community. A complete irrigation standards program includes not only standards documents, but also standards development procedures, testing and enforcement mechanisms for standards compliance, and vehicles for communication with all interested parties. A successful standards program necessarily combines both international and local elements.

Standards benefit the irrigation community by: facilitating comparable product information; setting performance and safety minimums; ensuring compatible connections; protecting consumers and suppliers alike from substandard equipment; and setting consistent procedures for field evaluation and acceptance. Benefits of special significance in developing irrigation markets include: assisting local manufacturers to improve and maintain quality; providing consumers with reliable and comparable technical information on products, systems, and practices; aiding educational efforts; and facilitating technology transfer.

Irrigation standards in developing markets facilitate adoption of high efficiency technologies because product failures are minimized. Thus standards build trade in developing markets by: increasing market size; educating consumers about important product selection criteria; eliminating unfair competition from substandard goods; and ensuring a uniform basis for product acceptance testing. A recent study of the developing Egyptian irrigation market supports these observations. Like Egypt, many irrigation markets throughout Asia, Africa and Latin America depend on a combination of locally produced and imported technologies, suggesting that the principles presented here may have broad application.

REFERENCES

1. ASAE. 1998. ASAE Standards 1998 (45th Edition). American Society of Agricultural Engineers, St. Joseph, MI 49085-9659 USA, 981 pages.
2. El-Gindy AM. 1994. Personal Communications. Dr. AM El-Gindy, Director, Agricultural Engineering Research Institute, Cairo, Egypt.
3. ISO. 1995. ISO 11545 Agricultural Irrigation Equipment - Centre-Pivot and Moving Lateral Irrigation Machines with Sprayer or Sprinkler Nozzles - Determination of Uniformity of Water Distribution. International Organization for Standardization, Geneva, Switzerland.
4. Solomon KH. 1994. Memorandum of Observations and Recommendations. Report to Dr. A. El-Beltagy, General Director, National Agricultural Research Program, Egypt, July 28, 1994. Center for Irrigation Technology, Calif. State University, Fresno, 5 p.
5. Solomon KH and Dedrick AR. 1994. International Standards for Irrigation. Irrigation Business and Technology, November 1994, The Irrigation Association, Fairfax, Virginia, USA, Vol. II(5):18.
6. Solomon KH and Dedrick AR. 1995. Standards Development for Microirrigation. In FR Lamm (editor), Microirrigation for a Changing World, Proceedings, 5th International Microirrigation Congress, April 2-6, 1995, Orlando, Florida, USA. ASAE, St. Joseph, MI, pages 303-313.
7. Solomon KH and Zoldoske DF. 1994. Establishing Irrigation Equipment Testing for Zimbabwe. World Agriculture 1994, Sterling Publications Ltd., London, January 1994, pages 96-98.
8. Solomon KH and Zoldoske DF. 1995. Backflow Prevention and Safety Devices for Chemigation. Proceedings, Dahlia Greidinger International Symposium on Fertigation, March 27-April 1, 1995, Technion, Haifa, Israel.
9. Zoldoske, DF. 1995. Personal Communication. David F. Zoldoske, Director, Center for Irrigation Technology, California State University, Fresno, California, USA. ■■

(Continued from page 61)

Agricultural Mechanization in Laos: A Case Study in Vientiane Municipality

In a nutshell, there is potential for increasing the cropping intensity on the part of farmers owning power tiller but cropping in rainy season only. This category of farmers have maximum average land holding size and hence if they could grow crops during dry season as well the production could be increased substantially. A study should be made to provide them with irrigation facilities during dry season. The yield of paddy in all cases in rainy season is lower compared to dry season. This is mainly due to insufficient drainage facilities. A study should also be made in this direction to improve the yield in the season. There is still underutilization of the agricultural implements due to ignorance among the farmers. The Agriculture Department should educate the farmers regarding the benefits of the use of farm tools and implements. Gradually, farmers could also be trained regarding the use, repair and maintenance of farm tools and implements. Bank loans and subsidies from the government could also be made available to the farmers who do not have enough money to buy the implements.

REFERENCES

Agricultural Statistics of Lao People's Democratic Republic. (1997). Ministry of Agriculture and Forestry, Vientiane, Laos.

Khoune S., (1998). Agricultural Mechanization in Laos: A Case Study in Vientiane Municipality. Unpublished thesis, AIT, Bangkok, Thailand.

Personal communication, Farm Machinery Section, Department of Agriculture and Extension, Ministry of Agriculture and Forestry, Laos.

Regional Office for Asia and the Pacific (RAP). (1998). Selected Indicators of Food and Agriculture Developments in Asia-Pacific Region, 1987-97. FAO of the United Nations, Bangkok, 1998. ■■

Agricultural Mechanization in Laos: A Case Study in Vientiane Municipality

by

Gajendra Singh
Professor
Agricultural and Food Engineering Program
School of Environment,
Resources and Development
Asian Institute of Technology
Bangkok, Thailand

Sackbouavong Khoune
Master of Science Student
Agricultural and Food Engineering Program
School of Environment,
Resources and Development
Asian Institute of Technology
Bangkok, Thailand

Abstract

Mechanization of the agriculture sector in Laos started with the introduction of rice mills followed by the use of tractors imported from the former Soviet Union. Gradually, threshers and power tillers became popular among the farmers. Vientiane Municipality, as a province, has the highest level of mechanization in Laos. This study is based on a survey of 48 farmers from 10 villages in four districts of Vientiane Municipality in 1998. Farms were divided into two main categories: using power tillers and the other, using traditional using animal drawn implements. The power tiller users were further divided into three subcategories: a) the farmers owning power tillers and using them both in rainy as well as dry season; b) farmers who hired and used power tillers in rainy and dry season; and c) farmers who owned power tiller but used it only in rainy season. Few farmers owning power tiller and farmers using animal drawn implements grew crops only in rainy season due to lack of irrigation facilities. The main staple crop is rice. The main sources of farm power are human labor, draft animals and power tillers. The average holding size for the surveyed farmers was 2.15 hectare. The yield of paddy crop varied from 2.3 to 5.8 t/ha in the dry season and from 1.4 to 4.8 t/ha in the rainy season in the survey area. The farmers owning and using power tillers in both rainy and dry season had the highest paddy yield. The cropping intensity of farmers having irrigation facilities and owning power tiller was highest at 1.87 followed by those hiring power tillers at 1.72. The family income of farms using power tillers was higher than the family income of farmers using animal-drawn implements.

Introduction

Lao PDR is a landlocked and mountainous country. Out of its total land area of 23.08 million ha, about 900,000 ha are under agricultural use, 800,000 ha under permanent pastures, and 12.55 million ha (54% of the total land area) under forest and woodland. About four-fifths of the country comprises of mountains and hence land transportation is very difficult. The river Mekong flows across a major stretch of Laos territory and shapes much of the life style of the people. The total population of Laos in 1996 was 5.035 million and its total agricultural population in the same year was 3.882 million (around 77% of the total population). The ratio of agricultural land to agricultural population is 0.23 hectare per person (RAP, FAO, 1998). Laos has a typical monsoon climate with distinct rainy and dry seasons. The average annual rainfall is about 2,020 mm and the average rainfall in the rainy season (May - September) is about 1,810 mm.

Agriculture in Laos is very traditional and often the farmers still walk behind the plow pulled by a swamp buffalo. The farm mechanization is at a low level due to lack of power, lack of trained operators and high cost of machines. Farm power shortage results in late land preparation, poor water management and late harvesting which ultimately affects the yield. Due to illiteracy among farmers, they have poor skill in handling farm machinery. There is also lack of engineering and repair services in Laos. The local manufacturing shops are able to produce only simple farm tools and implements like digging hoe, plow, comb harrow, pedal threshers, hand operated blade and sickles. All other farm machineries and spare parts are imported.

This paper presents the status of agricultural mechanization in Vientiane Municipality of Laos and compares the yield, labor used and cropping intensity of paddy fields among different farm categories. For farms of different categories, the family income has also been compared.

Status of Agriculture

Agriculture contributes 51.5% of the gross domestic product of the country. The total cultivated area in Laos is 745,500 hectare. Farmers own their land and most of the farmers adopt mono cropping. Farmers in the mountainous region prefer mixed cropping and grow mountain rice with annual crops. The farmers in the mountains practice shifting cultivation (Slash and burn). They mainly use hand tools and use of farm implements is hardly known to many farmers in the mountains.

Rice is the main staple food. In 1997, out of a cropped area of 658,740 hectare planted to cereals, rice was grown on an area of 601,295 hectare. The cropped area under dry season rice increased considerably from 17,962 hectare in 1996 to 26,645 hectare in 1997. Other crops grown by Lao farmers are corn, tubers, mungbean, soybean, peanut, tobacco, cotton, sugarcane, coffee, and tea (**Table 1**).

The production of the main crops is given in **Table 2**. Rice contributes the most to the total cereal production. The total cereal production in 1997 was 1.83 million mt of which 1.66 million mt was rice. The average rice yield was 2.76 mt/ ha. The annual production of coffee was 12,300 ton in 1997 and coffee is one of the few export products in Laos.

Animal husbandry supports agriculture in the form of draft animals used for seedbed preparation, transportation and post harvest operations. In addition to cattle and swamp buffalo raising, farmers in Laos also raise pigs and poultry. In 1997, the estimated number of cattle was 1.23 million, and that of swamp buffalo was 1.224 million. The number of pigs raised was about 181,000.

Irrigation water is one of the most important inputs to increase agricultural production. In fact most of the Lao government planning efforts in agricultural mechanization have been focussed on irrigation in order to provide the farmers with water for their additional crops during dry season as well as for rainfed crops during drought condition. The total irrigated area was 208,413

Table 1. Area Planted to Main Crops in Laos (Unit: ha)

Items	1985	1990	1995	1996	1997	Average annual growth rate	
						1996/1997	1985-1997
Cereal	700650	714849	603046	605711	658740	8.75	1.84
Rice	663487	650300	559889	553741	601295	8.59	-0.66
Rainy season low land rice	383133	392376	367263	363133	421050	15.95	1.21
Upland rice in rainy season	270354	245877	179033	172646	153600	-11.03	-4.68
Dry season rice	10000	12047	13593	17962	26645	48.34	9.12
Maize	26886	36670	29112	37380	38000	1.66	2.22
Starchy roots (tubers)	10277	27879	14045	14590	19445	3328	385
Vegetable	6941	7168	9462	14615	25500	74.48	12.45
Annual industrial crops	36315	54786	57857	57960	61245	5.67	2.45
Mungbean	2418	3602	3321	1680	1995	1.875	-3.21
Soybean	3054	5110	5906	3575	3115	-12.87	-3.84
Peanut	6614	6536	8258	9405	13985	4870	147
Tobacco	3650	11665	7410	7220	7500	3.88	5.08
Cotton	5214	6886	9642	9145	7210	-21.6	0.01
Sugar cane	2640	3538	2688	3395	3700	898	695
Coffee	12595	17066	20158	23145	23345	0.86	5.90
Tea	130	383	574	395	395	0.00	7.20

Source: Agricultural Statistics of Lao P.D.R., Vientiane, 1997.

Table 2. Production of Main Crops in Laos (Unit: mt)

Items	1985	1990	1995	1996	1997	Average annual growth rate	
						1996/1997	1985-1997
Cereal	1513898	1776321	1567431	1584094	1832300	15.69	3.35
Rice	1395177	1491495	1417829	1413500	1660000	17.44	0.56
Rainy season low land rice	1023345	1081127	1071337	1076000	1299500	20.77	2.70
Upland rice in rainy season	345314	369376	296108	266000	247000	-7.14	-3.27
Dry season rice	26518	40992	50384	71500	113500	5874	1370
Maize	33333	66566	50375	78095	78300	0.26	6.65
Starchy roots (tubers)	85388	218260	99227	92499	94000	1.62	-0.21
Vegetable	39351	53512	61727	88853	100000	12.55	6.33
Annual industrial crops	106959	178220	122692	146238	158205	8.18	0.51
Mungbean	1490	2609	2298	1157	1500	29.65	-1.48
Soybean	2058	4210	4837	3245	2295	-29.28	-3.46
Peanut	5162	6410	8443	11857	12000	1.21	2.33
Tobacco	15686	56883	26643	26040	28000	7.53	4.14
Cotton	2904	4928	8804	6760	7000	3.55	2.47
Sugar cane	73035	96360	62327	87058	95000	9.12	6.38
Coffee	6144	5204	8576	10020	12300	22.75	5.98
Tea	480	1616	764	101	110	8.91	-12.29

Source: Agricultural Statistics of Lao P.D.R., Vientiane, 1997.

hectare in 1997.

Status of Farm Mechanization

Rice mill was the first agricultural machinery imported and introduced in Laos in the 1930s and became quite popular. Later on large tractors (65 - 85 hp) imported from Russia, were introduced followed by pedal threshers imported from Japan. With the strategy of the Lao government changing towards open social - economic development in 1985, international organizations contributed tractors, threshers, rice mills, and shellers for soybean and corn. Gradually factories manufacturing rice mills were established in some of the provinces in the country.

The farm power in use in Laos consists of human, animal and mechanical power. Cattle and swamp buffalo are the main draft animals used on farms. The number of swamp buffalo used as draft animals was 119,100 in 1995. Single-beam plow with single steel moldboard, harrow and leveling boards are the main animal drawn implements. Farmers usually have their own animal drawn implements. **Table 3** shows the estimated number of various farm equipment used in selected provinces of Laos in 1997. The maximum number of tractors, power tillers and threshers are being used in Vientiane province whereas rice mills are concentrated in Savannakhet, Khammouane and Champasack provinces. Pedal threshers are mainly used in Saravane province. The four-wheel tractors imported from the former Soviet Union are still widely used. The small tractors and power tillers are replacing the draft animals for land preparation. With the increase of the double crop rice area, the demand for small tractors and power tillers is increasing. These are being imported along with cage wheels, plow, harrow and trail-

Table 3. Estimated Number of Farm Machineries in Selected Provinces of Laos, 1997

Provinces	Number of farm machines					
	Tractors	Power tillers	Thresher	Pedal thresher	Harvesters	Rice mill
Vientiane Municipality and Vientiane Province	404	3,519	368	-	9	577
Bolikahamsay	30	750	40	-	-	600
Khammouane	15	20	25	-	-	800
Savannakhet	17	1,141	54	-	-	804
Champasack	7	148	291	-	-	989
Saravane	15	100	10	1,000	-	700
Total	488	5,678	788	1,000	9	4,470

Source: Farm Machinery Section, Department of Agriculture and Extension, Ministry of Agriculture and Forestry, Laos

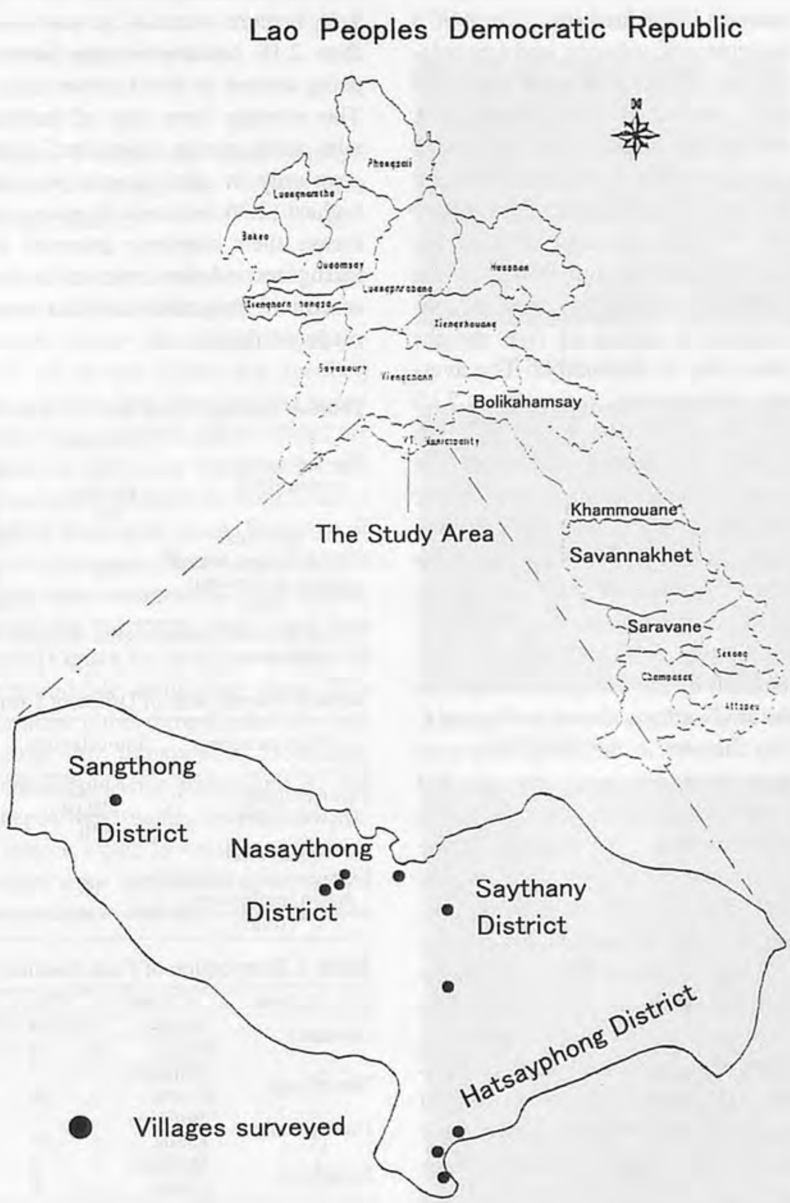

Fig. 1 Map of Vientiane Municipality showing villages surveyed.

ers with rubber wheels for transportation. The production of rice is often hampered by the lack of draft power to do agricultural operations on time. Therefore, prospects of farm mechanization in Laos are good.

Agricultural Mechanization in Vientiane Municipality

Vientiane, capital of Laos, is the largest city in the country and is located on the bank of the Mekong River. The area of Vientiane province is 3,920 km^2 consisting of 8 districts, 486 villages, and a population of 54,160. The total harvested area planted to main crops (rice, maize and vegetables) was about 62,425 hectare. It is the third largest rice producing area in the country and contributes about 11% of the total rice production. Much of the rainfall in the survey area is confined to a period of five months from May to September. The average temperature varies from 22.3 °C (in December) to 29.7 °C (in April). Sometimes the rains are quite erratic leading to either draught or flood and thus affecting yield. In this study, 48 farmers were randomly selected from 10 villages of four districts in the Vientiane Municipality. A map showing the location of the villages surveyed in the study area is shown in **Figure 1**. The farmers in the study area own their land. Farmers, who do not have enough land, rent land from other owners. The farmers in the area also exchange labor during peak demand period of transplanting and harvesting of paddy crop.

Based on the level of mechanization, the 48 farms under study were divided into two main categories: farms using power tillers (P) and traditional farms (TR) using animal drawn implements. The power tiller users were further divided into three sub-categories as the farmers who own power tiller and use them in dry and rainy season (PRD), farmers who hire power tillers in both rainy and dry season (PRDH) and those who own power tillers and use them in the rainy season only (PR).

The farm size in the survey area ranged from 0.8 to 4 hectare. The average holding size for selected farmers in the four districts was 2.15 hectare. The average farm size of farmers who used power tillers was higher than the average farm size of farmers who used animal drawn implements (**Table 4**). The average farm size of farmers using animal drawn implements was only 1.86 hectare whereas it was more than 2.10 hectare for the farmers using owned or hired power tillers. The average farm size of farmers who used power tillers and grew crop only in rainy season was the highest (2.36 hectare). They can increase their cropping intensity by taking second rice crop in the dry season if irrigation facilities were made available.

The average family size, in the case of farmers using power tillers, was more than 6 whereas the average family size of farmers using animal drawn implements was only 5 (**Table 5**). Average number of labor in the family of farmers using animal drawn implements was also low (three) compared to farmers using power tillers (more than three).

Table 6 shows the population of cattle and swamp buffaloes in the survey area. Farmers who use power tillers on the farms also raise cattle and swamp buffaloes to sell them in market for meat. Of the 48 farmers interviewed in the survey area, only four of them in Sangthong district used animals as the draft power.

The population of tractors and power tillers owned by farmers in survey area is shown in **Table 7**. The maximum number of tractors and power tillers was owned by those farmers who could use them in both rainy and dry season. Of the

Table 4. Average Farm Size of Farmers in Different Categories

	Category	No.	Mean (ha)	Stdev	Max	Min
Farmers using power tillers	PRD	28	2.11 a	0.97	4.00	1.00
	PRDH	9	2.21 a	1.11	4.00	0.85
	PR	7	2.36 a	1.38	4.24	0.96
Sub-Total		44	2.16	1.05	4.24	0.85
Farmers using animal-drawn implements	TR	4	1.86 a	0.42	2.20	1.28
Total		48	2.15	1.01	4.24	0.85

Means followed by same letter indicates that there is no significant difference at 95% level of significance.

Table 5. Family Size of Different Farm Categories

Main category	Sub-category	No.	Average	
			Family size (person)	Labor (person)
Farmers using power tillers	PRD	28	6.6	3.3
	PRDH	9	6.0	3.0
	PR	7	7.0	3.2
Sub-total		44	6.6	3.2
Farmers using animal-drawn implements	TR	4	5.0	3.0
Total		48	6.4	3.2

Table 6. Distribution of Farm Animals in Study Area of Four Districts

Districts	Item	PRD	PRDH	PR	TR	Total
Saythany	Buffalo	9	0	0	0	9
	Cattle	37	2	7	0	46
Nasaythong	Buffalo	2	0	0	0	2
	Cattle	20	15	0	0	35
Hatsayphong	Buffalo	1	0	1	0	2
	Cattle	19	0	0	0	19
Sangthong	Buffalo	0	0	9	4	13
	Cattle	0	0	6	3	9
Total	Buffalo	12	0	10	4	26
	Cattle	76	17	13	3	109
	Total	88	17	23	7	135

Table 7. Distribution of fArmers Using Power Tillers and tRactors in Survey Area

Farmers categories	No.	District								Total	
		Saythany		Nasaythong		Hatsayphong		Sangthong			
		No.		No.		No.		No.			
		P.tiller	Tract	P.tiller	Tract	P.tiller	Tract	P.tiller	Tract	P.tiller	Tract
PRD	28	10	1	8	1	9	1	-	-	27	3
PRDH	9	H	-	H	1	H	-		-		1
PR	7	2	2	-	-	2	-	2	-	6	2
TR	4	-	-	-	-	-	-	-	-	-	-
Total	48	12	3	8	2	11	1	2	-	33	6
No. of farmers		16		12		14		6			

Legend: H: Hired power tiller; P.tiller: Power tiller; Tract: Tractor

total 48 farmers, 35 owned power tiller; (33) tractor (6); and nine farmers hired power tillers from other owners. Only four farmers used draft animals for land preparation. Tractors were of 65 hp and were mainly used for threshing and land preparation in the dry condition. Most of the power tillers were imported from Thailand and China and their engine power ranged from 8 to 14 hp. The implements supplied with power tillers were disk plow, steel comb harrow, irrigation pump and cage wheels. The use of power tillers was still limited to soil preparation. Power tillers were not equipped with rotary tillers. For road transportation, power tillers were equipped with rubber tyres and trolley.

The distribution of implements owned by farmers in each category is shown in **Table 8**. Generally, the farmers who own power tillers and tractors also have plow, harrow, trailer and pump as attachments. The farmers who do not possess there implements, hire them.

The cost of a power tiller with implements set, sold in the local market in 1998, was about 1,500,000 - 8,000,000 kip (1 US$= 4,800 kip). The cost of tractor was about 2,000,000 - 6,000,000 kip. The farmers complained of the high cost of power tiller. They had to sell 8 - 9 mt of rice for buying one Thai-made power tiller.

Farm Practices and Implements used in Vientiane Municipality

In the past, farmers used cattle and swamp buffalo with traditional comb harrow for tillage. Now the use of power tillers for seedbed preparation has become quite popular. The wooden plow used for plowing has been replaced by the steel plow (**Figure 2**) which has a life of about four years. The price of steel plow was 28,800 kip (6 US$). The most commonly used implement for harrowing was comb harrow (**Figure 3**). Its price was 28,800 kip and life about four years. The farmers either broadcasted the rice seeds or transplanted seedlings manually. After transplanting, the weeds were mainly controlled by irrigation water. In some areas, herbicides were applied by sprayer and sometimes chemical powder was sprayed by hand. The farmers also used blade tools (**Figure 4**) for cutting the weeds. The price of blade tools was about 3,000-6,000 kip (US$0.60-1.25) having life of about

Fig. 2 Steel plow used in Vientiane Municipality.

Fig. 3 Comb harrow used in Vientiane Municipality.

Fig. 4 Blade tools used in Vientiane Municipality.

Table 8. Equipment Owned by Surveyed Farmers in Various Categories

Item	Farm category				Total
	PRD	PRDH	PR	TR	
Number of farmers	28	9	7	4	48
Animal-drawn plow	-	-	-	11	11
Animal-drawn harrow	-	-	-	7	7
Power tiller-drawn plow	27	-	6	-	33
Pump	4		1		5
Power tiller-drawn harrow	27	-	6	-	33
Power tiller-trailer	28		7		35
Tractor-drawn plow	1	-	1	-	2
Tractor-drawn harrow	1		1		2

three years.

Harvesting is the most labor-intensive and most expensive operation in rice production. In the survey area, paddy was harvested manually using sickle. About 40 person-days were required to harvest one hectare of paddy crop. The cost of sickle was about 3,000-5,000 kip (US$0.6-1.0).

In Vientiane Municipality there were 66 pump stations and 2,857 places of temporary weir, permanent weir and reservoirs/ponds. These irrigation schemes supplied water to 34,878 ha crop area in rainy season and 11,252 ha in dry season. Water for irrigation was pumped from Mekong and NumNgum river using electric motor (37kW - 75kW) or diesel engine (7hp - 14 hp) driven pumps. Farmers using irrigation water from NumNgum river had to pay 15,000 kip (US$3.1) per hectare in Nasaythong district. In the rainy season, the cost of irrigation water from pumps was 36,000 kip/ha (US$7.5/ha) and for dry season it was 54,000 kip/ha (US$11.25/ha).

Much of the rice crop is threshed on contract basis by farmers or private contractors owning threshers. The contractor was paid one bag of paddy after threshing twenty bags. The threshing cost varied from 1,000 – 1,500 kip per bag (1 bag = 65-80 kg). The price of a thresher in 1998 was 946,800 kip (1,971 US$).

In Vientiane Municipality, on an average, there is one rice mill for every two villages. The charge of milling and polishing was about 60 kip per kg of rough rice.

The roads in the villages are not in good condition. The products were often transported manually or by hiring power tiller with trailer. The charge for transportation was 500 kip (US$0.1) per bag per 5 km of distance.

The farmers do minor repairs and maintenance of the farm implements themselves; there was hardly any shop for repairs in the survey area. For major repairs, the machine is driven to the supplier or some recognized private workshop that sometimes took 4-5 days to get the machine repaired. There were a few shops in Vientiane Municipality that could fabricate simple and small farm tools and implements based on the designs from other countries.

Paddy Yield and Cropping Intensity

Paddy yield in the survey area varies from 1.4 to 4.8 ton/ha in rainy season and from 2.3 to 5.9 ton/ha in dry season. The average paddy yield of different categories of farmers is shown in **Table 9**. The farmers owning power tillers and using irrigation facilities (PRD) had the highest yield in the rainy season (3.2 mt/ha) and dry season (4.1mt/ha). The farmers who grow crop both in rainy and dry season using hired power tillers (PRDH) had slightly lower yield (2.7 mt/ha in rainy season and 3.6 mt/ha in dry season) compared to PRD category (3.2 mt/ha in rainy season and 4.1 mt/ha in dry season). The average yield of paddy in the farms using power tiller was 3.0 mt/ha, which was slightly higher than the yield in the farms using animal drawn implements (2.9 mt/ha). The yield of dry season paddy is higher in all cases compared to the rainy season paddy. Some of the rainy season crops are affected by flood, which reduces the average yield for the season.

In Vientiane Municipality, only the farmers using power tillers grew crops both in rainy as well as dry season. Few power tiller farmers grow crops only in rainy season due to lack of irrigation water in dry season. Similarly, farmers using animal-drawn implements grow crops only in rainy season. The cropping intensity for different categories of farms in the survey area is shown in **Table 10**. The cropping intensity on farms with irrigation water was very high, both on owned power tiller farms (1.87) and farms using rented power tiller (1.72). The cropping intensity was only 100% on both power tiller and animal operated farms where no irrigation water was available.

Human labor consisting of family labor and hired labor was mainly used for broadcasting seeds, transplanting of rice and harvesting. The average family and hired person-

Table 9. Average Paddy Yield for Different Categories of Farms

Item	Category	No. of farmers	Average cultivated area (ha) Rainy season	Average cultivated area (ha) Dry season	Average yield (mt/ha) Rainy season	Average yield (mt/ha) Dry season
Farmers using power tiller	PRD	28	1.98	1.65	3.24 a	4.10 c
	PRDH	9	2.13	1.52	2.68 b	3.58 c
	PR	7	1.81		2.41 b	-
Sub-Total		44	1.97	1.58	2.99	3.99
Farmers using animal drawn implements	TR	4	1.62	-	2.86 ba	-
All farmers		48	1.79	1.58	2.98	3.99

Means followed by the same letter indicates that there is no significant difference at 95% level of significance.

Table 10. Cropping Intensity in the Survey Area, by Category

Item	Category	No. of farmers	Cropping intensity mean (%)
Farmers using power tillers	PRD	28	187 a
	PRDH	9	172 a
	PR	7	100 b
Sub-total		44	170
Farmers using animal drawn implements	TR	4	100 b
All farmers		48	164

Means followed by the same letter indicates that there is no significant difference at 95% level of significance.

Table 11. Human Labor Used in Various Farm Operations for The Rainy Season Rice Crop (Unit: Person-days/ha)

Item	Farmers		Tillage			Uprooting seedlings & transplanting			Harvesting			Total
	Category	No.	Primary	Secondary								
			FL	FL	Total	FL	HL	Total	FL	HL	Total	
Farmers using power tillers	PRD	28	4	4	8	32	18	50	21	19	40	98
	PRDH	9	0	0	0	24	33	57	23	37	60	117
	PR	7	3	3	6	28	12	40	19	13	32	78
Sub-total		44	2.3	2.3	4.6	28	21	49	21	23	44	97.6
Farmers using animal-drawn implements	TR	4	23	9	32	37	6	40	22	9	31	106

FL: Family labor; **HL**: Hired labor

days/ha used on the farms during rainy season are shown in **Table 11**. The maximum labor requirement was for transplanting and harvesting operations for each farm category. For tillage, the farmers using animal drawn implements used more person-days/ha compared to the farms using power tillers because the power tillers finish the tillage faster. The average person-days/ha required by the farmers using hired power tillers was comparatively high as they use more labor for transplanting and harvesting paddy.

Table 12 shows the average production cost per hectare for paddy crop and the net farm income. The cost includes cost of all inputs and costs of operations which includes fixed and variable costs. The fixed cost of a machine includes depreciation and interest and its variable cost includes cost of labor, fuel, oil, and repair and maintenance. The farmers, using own power tiller in rainy and dry season, had the highest average net farm income per hectare of about 2,513,000 kip. This was due to the fact that they had the highest paddy yield both in rainy as well as in dry seasons. The farmers using own power tiller but planting only one crop in the rainy season had the lowest net farm income among all categories.

Their fixed cost was maximum (700,000 kip/ha) as these farmers in the survey area had purchased new power tillers and their income was low because they grew only rainy season crop. The fixed cost of farmers using hired power tillers and taking both rainy and dry season crops was 149,000 kip and was minimum among all the categories since they did not own the power tillers. The farmers using animal drawn implements did not use fertilizer in the areas surveyed.

The average annual family income of farmers in different categories is summarized in **Table 13**. The annual income is the sum of income from paddy crop, livestock, fruits, vegetables and other sources such as handicraft, and renting out animals, power tiller, thresher and tractors. The average annual family income of farmers using own power tiller and cropping both in rainy and dry season was maximum (10,790,000 kip). The return from paddy contributed most to the total family income. The total annual family income of farmers using hired power tillers and cropping both in dry and rainy seasons was 9,339,000 kip. The farmers in this category, besides growing paddy in both seasons, also produced fruits and vegetables and also had income from business. Though they did not raise livestock, they had the maximum income from sources other than paddy. The farmers, using own power tiller in only rainy season and the farmers using animal drawn implements, had significantly lower total family income compared to the other two categories because they could grow only one crop of paddy. The farmers using animal-drawn implements received maximum returns from the livestock, among all the categories.

(Continued on page 54)

Table 12. Costs and Net Farm Income per Hectare for Rice Crop

Category	No.	Cost (10^3kip/ha)						Gross Return	Net farm Income
		Fixed	Variable	Seed	Fertilizer	Land tax	Total cost		
PRD	28	253 b	282 d	98	125	0.3	761	3274 f	2513 j
PRDH	9	149 a	386 e	115	84	0.3	738	2702 g	1964 k
PR	7	700 c	397 e	74	90	0.3	1264	2168 h	904 l
Sub average		347	361	85	99	0.3	896	2680	1783
TR	4	288 b	378 e	54	0	0.3	724	2574 g	1850 k

Means followed by the same letter indicates that there is no significant difference at 95% level of significance.

Table 13. Total Annual Family Income by Farm Category

Category	Income from rice	Income from sources other than rice, (10^3 kip/year)					Total annual family income
		Income from livestock	Income from fruits and vegetables	Farm activities and renting out land	Other	Sub total	
PRD	9,122 a	314	335	621	398	1668 c	10,790 f
PRDH	7,168 a	0	500	887	784	2171 d	9,339 f
PR	1,636 b	9	0	1,263	679	1951 d	3587 g
Sub average	6,329	200	317	788	523	1818	8,147
TR	2,997 b	618	250	0	100	968 e	3,965 g
Average	5,230	235	310	713	487	1745	6,975

Means followed by the same letter indicates that there is no significant difference at 95% level of significance

Extent of Integrated Mechanization Degree of Large Farms

by
Dr. Wu Ziyue
Associate Professor
Dept. of Agricultural Mechanization
Nanjing Agricultural University
Puzheng, Nanjing. 210032
Jiangsu, China
E-mail: njnjhx@jlonline.com

Wang Yaohua
Professor
Dept. of Agricultural Mechanization
Nanjing Agricultural University
Puzheng, Nanjing. 210032
Jiangsu, China

Abstract

The extent of integrated mechanization at Huanghai State Farm in Jiangsu province of China was systematically studied with multidimensional grey assessment theory and grey modelling theory. Of the 22 factors influencing the extent of integrated mechanization six most important ones are: intact rate, newness coefficient, total power, total plantation area, matching ratio, and population of tractors. They are utilized to establish three sub-models which can affect the rules of integrated mechanization from various points of view. As these models are of high precision, all of them can be used to forecast and control the degree or extent of agricultural mechanization degree.

Introduction

The Huanghai State Farm is a large state-owned enterprise for agricultural production. Its extent of integrated mechanization has reached up to 80 percent. The total power of agricultural machinery is 27 million watts. The total arable land area is about 12000 ha. Agricultural mechanization is exerting its more important roles in ensuring high yield, and added value of the products, hence a study of mechanization of state farms is of great value.Integrated mechanization is the central index standing for the level and profitability of agricultural mechanization. The subject has been qualitatively researched by many scholars, but there are not many reports on quantitative relationship available. Consequently, the author selected the Huanghai State Farm from the reclamation system in Jiangsu province as the venue of the study.

According to the annual statistical reports on agricultural mechanization of the state farm, the grey quantitative relationship between the integrated extent of mechanization its influential factors was established by multidimensional grey assessment theory and gray modelling theory. This provided the theoretical basis for forecasting and controlling agricultural mechanization in the state farm.

Six Important Influential Factors

There are many kinds of probable factors that influence the extent of integrated mechanization degree(Y_1). By both qualitative and quantitative analyses, some less important factors are discarded and the most important ones are classified by their nature and fluctuating degree. It is necessary to ensure the availability of the value of these factors. Based on the above principles, the influential factors on the extent or degree of integrated mechanization are divided into five main types with a total of 22 sub-factors.

Type 1 Equipment Level

The five sub-types and their symbols are: 1) total power of agricultural machinery, (X_{11}); 2) power of large-medium tractors (X_{12}); 3) power of small tractors (X_{13}); 4) power of harvesters (X_{14}); and 5) total power of agricultural machinery per hundred acres of cultivated land (X_{15}).

Type 2 Plantation Condition

The four sub-types are: 1) total tillaged area (X_{21}); 2) wheat area (X_{22}); 3) paddy rice area (X_{23}); and 4) cotton area (X_{24}).

Type 3 Intact Condition

Type 3 has six sub-types and symbols as follows: 1) net value of fixed assets (X_{31}); 2) annual fund for purchasing implements (X_{32}); 3)oil consumption (X_{33}); 4) consumption of electricity for agricultural operations (X_{34}); 5) newness coefficient of agricultural machinery (X_{35}); and 6) intact rate of agricultural machinery (X_{36}).

Type 4 Operation Level

For type 4, there are three sub-types and symbols as follows: 1) total operation quantity (X_{41}); 2) operation quantity of large-medium tractors (X_{42}); and 3) harvesting operation quantity (X_{43}).

Type 5 Matching Level

Type 5 carries four sub-types and symbols, namely; 1) number of drawn implements (X_{51}); 2) chain tractors quantity (X_{52}); 3) large-medium wheeled tractors quantity (X_{53}); and 4) matching ratio (X_{54}).

According to annual statistics on agricultural mechanization management of state farms from 1991 to 1997, the data-base used for analysing influential factors on the degree of integrated mechanization in Huanghai state farm is established. The grey correlative degree of each factor is obtained by a grey correlative analysis program. The calculation results are shown in **Table 1**.

In view of the average values of various factors for each type, the intact condition is most important.

Table 1. Grey Correlative Degree of Each Factor

Factors		Y_1
	X_{11}	0.765
	X_{12}	0.641
Type 1	X_{13}	0.684
	X_{14}	0.611
	X_{15}	0.711
	Average	0.682
	X_{21}	0.957
Type 2	X_{22}	0.878
	X_{23}	0.835
	X_{24}	0.445
	Average	0.779
	X_{31}	0.855
Type 3	X_{32}	0.647
	X_{33}	0.862
	X_{34}	0.777
	X_{35}	0.929
	X_{36}	0.986
	Average	0.843
	X_{41}	0.740
Type 4	X_{42}	0.833
	X_{43}	0.752
	Average	0.775
	X_{51}	0.571
Type 5	X_{52}	0.524
	X_{53}	0.659
	X_{54}	0.842
	Average	0.649

The order is followed by operation level, plantation condition, equipment level and matching level. Therefore, it is necessary to pay more attention to the intact condition of agricultural machinery.

Based on the order of grey correlative degree for various factors in each section, a couple of factors with higher degree are selected to build important factor groups which contains X_{36}, X_{35}, X_{42}, X_{21}, X_{11} and X_{54}.

Grey Model (1,N) [2]

The grey derivative equation of GM(1,N) is followed by the equation:

$$\frac{dx_1^{(1)}}{dt} + a_1\chi^{(1)} = b_2x_2^{(1)} + \Lambda + b_Nx_N^{(1)}$$

Assume $\chi^{(1)}$ is the background value for $\frac{dx_1^{(1)}}{dt}$, the parameter of GM(1,N) is:

$$\hat{a} = [a_1, b_2, \cdots, b_N]^T$$

$\hat{a}$ is derived by minimum double-multiplication principle.

$$\hat{a} = \left(B^TB\right)^{-1}B^TY_N$$

$$B = \begin{bmatrix} -Z_{1(2)}^{(1)} & X_{2(2)}^{(1)} & \cdots & X_{N(2)}^{(1)} \\ -Z_{1(3)}^{(1)} & X_{2(3)}^{(1)} & \cdots & X_{N(3)}^{(1)} \\ \vdots & \vdots & & \vdots \\ -Z_{1(n)}^{(1)} & X_{2(n)}^{(1)} & \cdots & X_{N(n)}^{(1)} \end{bmatrix}$$

$$Z_{1(k)}^{(1)} = \frac{x_{1(k)}^{(1)} + x_{1(k-1)}^{(1)}}{2}$$

$$Y_N = \begin{bmatrix} X_{1(2)}^{(0)} \\ X_{1(3)}^{(0)} \\ \vdots \\ X_{1(n)}^{(0)} \end{bmatrix}$$

The form of index response of GM(1,N) is: **equation 1**.

These coefficients b_2, b_3, ..., b_N display the correlative degree between indices and factors. If $b_i > 0$, there is a promotion of factor X_i to index X_1. If $B_j<0$ there is resistance of factor X_j to index X_1. The value of a_1 means the coordinate degree between index x_1 and various factors. It is also called the developing coefficient for $x_1^{(1)}$. For an economic system to meet running principle, there is surely be $a_1 \geqq 0$.

Establishment and Assessment of Sub-models

Based on the valid formula of GM(1,N), the program to calculate was created. The comparative analysis between coefficient and model was carried out for the establishment of a couple of satisfactory sub-models. The values of coefficients are shown in **Table 2**.

The forms of indices corresponding to three models are each:

Model I

This model displays the grey quantitative relationship between objective Y_1 and four factors X_{15}, X_{21}, X_{36}, and X_{54}. Coordinate coefficients of the four factors are suitable, hence an ideal model. Of the four numerals of coefficients, b_5 is the largest, 2.106, which implies that the intact rate of agricultural machinery is the most influential factor on the integrated mechanization degree. b_2=0.053 displays the smallest influence of total power per hundred area of arable land on the degree of integrated mechanization. We ought to increase the total power per hundred

$$\begin{cases} x_{1(k+1)}^{(1)} = \left(x_{1(1)}^{(0)} - \frac{1}{a_1}\sum b_i x_{i(k+1)}^{(1)}\right)e^{-a_1k} + \frac{1}{a_1}\sum b_i x_{i(k+1)}^{(1)} \\ x_{1(k+1)}^{(0)} = x_{1(k+1)}^{(1)} - x_{1(k)}^{(1)} \end{cases}$$

Equation 1

Table 2. Values of Coefficients for GM(1,N)

Models	I	II	III	Coefficient
Y_1	2.306	2.230	1.776	$\leftarrow a_1$
X_{15}	0.053		-0.322	$\leftarrow b_2$
X_{14}	-	0.057	0.421	$\leftarrow b_3$
X_{21}	-0.375	-0.334	-0.104	$\leftarrow b_4$
X_{36}	2.106	2.071	1.861	$\leftarrow b_5$
X_{54}	0.446	0.385	-	$\leftarrow b_6$

$$x^{(1)}_{1(k+1)} = \left[0.795 - \frac{1}{2.306}\left(0.053x^{(1)}_{15(k+1)} - 0.375x^{(1)}_{21(k+1)} + 2.016x^{(1)}_{36(k+1)} + 0.446x^{(1)}_{54(k+1)}\right)\right]e^{-2.306k}$$
$$+\frac{1}{2.306}\left(0.053x^{(1)}_{15(k+1)} - 0.357x^{(1)}_{21(k+1)} + 2.016x^{(1)}_{36(k+1)} + 0.446x^{(1)}_{54(k+1)}\right)$$
$$x^{(0)}_{1(k+1)} = x^{(1)}_{1(k+1)} - x^{(1)}_{1(k)}$$

Equation Model I

$$x^{(1)}_{1(k+1)} = \left[0.795 - \frac{1}{2.23}\left(0.057x^{(1)}_{14(k+1)} - 0.334x^{(1)}_{21(k+1)} + 2.071x^{(1)}_{36(k+1)} + 0.385x^{(1)}_{54(k+1)}\right)\right]e^{-2.23k}$$
$$+\frac{1}{2.23}\left(0.057x^{(1)}_{14(k+1)} - 0.334x^{(1)}_{21(k+1)} + 2.071x^{(1)}_{36(k+1)} + 0.385x^{(1)}_{54(k+1)}\right)$$
$$x^{(0)}_{1(k+1)} = x^{(1)}_{1(k+1)} - x^{(1)}_{1(k)}$$

Equation Model II

$$x^{(1)}_{1(k+1)} = \left[0.795 - \frac{1}{1.776}\left(-0.322x^{(1)}_{15(k+1)} + 0.421x^{(1)}_{14(k+1)} - 0.104x^{(1)}_{21(k+1)} + 1.861x^{(1)}_{36(k+1)}\right)\right]e^{-1.776k}$$
$$+\frac{1}{1.776}\left(-0.322x^{(1)}_{15(k+1)} + 0.421x^{(1)}_{14(k+1)} - 0.104x^{(1)}_{21(k+1)} + 1.861x^{(1)}_{36(k+1)}\right)$$
$$x^{(0)}_{1(k+1)} = x^{(1)}_{1(k+1)} - x^{(1)}_{1(k)}$$

Equation Model III

acre of arable lad to enable the role of this factor to be fully exerted.

Model II

This model reflects the grey quantity relationship between Y_1 and the four factors X_{14}, X_{21}, X_{36}, and X_{54}. It is basically the same as Mode I even as X_{15} of which was replaced by X_{14}. Among the four factors, the influence of X_{36} is still the largest followed by X_{54}. But enlarging X_{54}, the extent of selecting operation implements will change more broadly. This will be advantageous in promoting the integrated degree of mechanization.

Model III

This model depicts the grey quantity relationship between Y_1 and the four factors X_{15}, X_{14}, X_{21}, and X_{36}. It combines the advantages of the above two models. Because of a decrease in a_1, the index will be more coordinate with the factors and X_{14} will be more influential on Y_1.

Conclusions

That the higher the level of equipment, the higher the integrated degree of mechanization is not correct. This is because the correlative degree of equipment level on Y_1 is smaller in comparison with other levels.

That the more fund expended in purchase and management of agricultural machinery, the higher the integrated degree of mechanization is also incorrect. This is because the correlative degree of X_{32} on Y_1 is the smallest in the all factors of Type 3.

Three sub-models unravelled the influential rules of some important factors on Y_1. These models represented the coordinate structure of selection agricultural machinery on this farm.

The coefficient of each factor in the models scientifically illustrated a harmony degree between indices and factors. Due to high precision, all models can be used to forecast and control agricultural mechanization degree.

REFERENCES

Wan Ishak bin Wan Ismail, Expert System for Crop Production Machinery System AMA 1994(3):55-62

Wu Ziyue, 1987. Multidimensional Grey Assessment on Influential Factors on Agricultural Mechanization Degree of State Farms. TRANSACTIONS of the CSAE 13(4): 8-12

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Scope of Mechanization in Lac Production

by

Niranjan Prasad
Scientist
T.O.T. Division
I.L.R.I., Namkum
Ranchi - 834010
India
E-Mail:tot@ilri.bih.nic.in
FAX:(+91)-651-520202

S.K. Pandey
Scientist
L.P.P.D. Division
I.L.R.I., Namkum
Ranchi - 834010
India

K.K. Kumar
Director
I.L.R.I., Namkum
Ranchi - 834010
India

S.C. Agarwal
Ex-Director
I.L.R.I., Namkum
Ranchi - 834010
India

Abstract

Studies were undertaken to determine the status of mechanization and its scope in lac production operations. In order to collect the information, scientists working in the field of lac production and lac growing farmers were contacted. Relevant literatures were reviewed. It was found that locally manufactured hand tools are mostly used in different lac cultivation operations, viz. Pruning, inoculation, "phunki" removal, harvesting and lac scraping. However, some research works have been carried out at the Birsa Agricultural University (B.A.U.), Ranchi and Central Institute of Post-harvest Engineering and Technology (CIPHET), Ludhiana to mechanize lac scraping. The B.A.U., Ranchi has developed a manual lac scraping machine of 5 kg/hr lac stick scraping capacity. CIPHET, Ludhiana has developed a power operated lac scraping -cum-grading machine of 20 kg/hr capacity. There is ample scope for mechanization in other lac production operations apart from scraping either by improving the design of existing hand tools to improve their capacity and efficiency or by designing new low-cost equipment.

Introduction

Lac is the hardened resin secreted by the tiny lac insect which thrives on the cell sap of certain host plants, namely; Palas (*Butea monosperma*), Kusum (*Schleichera oleosa*), Ber *(Ziziphus sp.)*, Ficus (*Ficus benghalensis*) etc. India is a major lac producer in the world and exports lac to several countries like Indonesia, United States of America, Germany etc. Some of the major uses of lac include lacquering, enamelling, scaling, polishes, insulations, medicines, gaskets, abrasives, adhesives etc. Lac dye isolated from the effluent water obtained during lac processing is used for colouring of cloth, animal fibres, soft drinks, jam etc. (Mukhopadhyay and Muthana, 1962).

Lac production involves pruning, inoculation, phunki removal, harvesting and lac scraping. Farmers perform these operations manually using traditional equipment. The traditional equipment need modification to increase the efficiency and ultimately the production. This paper discusses the existing status of mechanization and scope for further improvement.

Status of Mechanization and Scope of Improvement

Pruning

The lac insect thrives best on tender shoots rather than on old and woody ones. In order to provide a suitable ground for the insect to feed well and thrive upon, the host-plant must be receptive and sustainable. For young plants no particular preparation is required to receive their first infection since there is an abundance of tender shoots. For older plants, however, a process of pruning is to be observed prior to infection in order to stimulate the production of fresh and succulent branches. Ordinarily, branches less than an inch in diameter are only advisable to be pruned.

The majority of farmers do pruning with axe (**Fig. 1**) and this may explain to some extent the thickness of the branches cut. Proper pruning cannot be done with an axe. If branches of the thickness recommended are cut with axes they will either break or split. Some farmers use sharp edge knife (**Fig. 2**) for pruning which is better than the axe

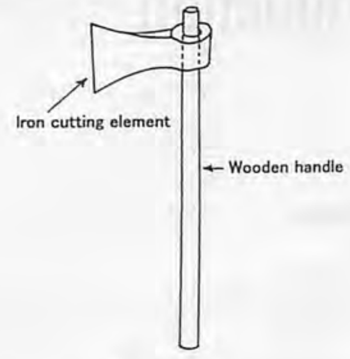


Fig.1 Axe.

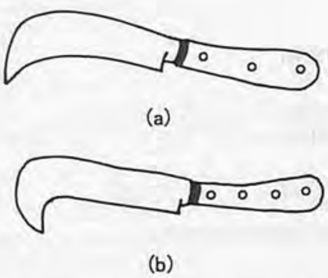


Fig.2 (a)Knife with non-hooked blade.
(b)Knife with hooked blade.

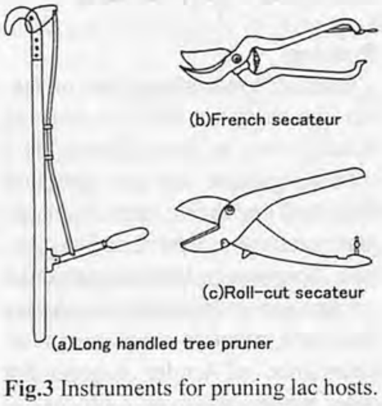


Fig.3 Instruments for pruning lac hosts.

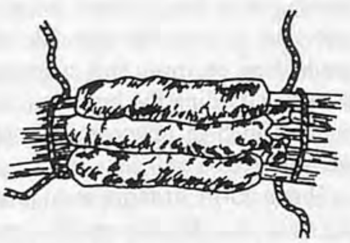


Fig.4 Bundle of brood lac sticks.

for pruning.

The ideal pruning instruments are long handle tree pruner (**Fig. 3a**) and secateurs (**Fig. 3b**, **c**). The long handle tree pruner is most suitable for pruning. This type of pruner is extremely simple in construction and could easily be made by village black smith if he has a sample to copy (Glover, 1937).

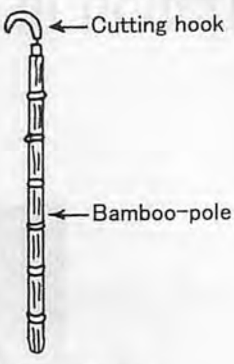
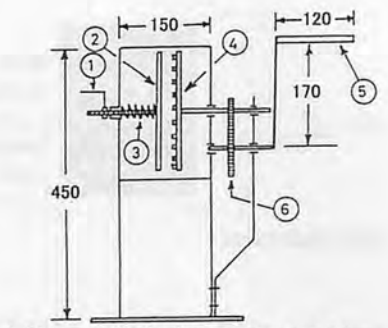


Fig.5 Phunki hook.



1. Disk gap adjusting lever. 2. Stationary disk. 3. Spring. 4. Scraping disk. 5. Operating handle. 6. Gear.

Fig.6 Manually-operated lac scraper.

There are two types of secateurs - roll-cut secateur and the French secateur illustrated in Fig. 3b,c. The roll-cut secateur are much better and easier to use but are easily damaged by careless use. As in general, untrained workers do pruning, the French secateurs are recommended.

There is scope of improvement in the existing long handle tree pruner by increasing it's mechanical advantage either by changing the leverage mechanism or by providing gear system. There is also scope of making power-operated tree pruner with rotary cutting blade operated by small battery driven motor.

Inoculation

The method by which the lac insects are introduced on to a lac host is known as inoculation. It involves the simple process of cutting lac-bearing twigs from an infected tree a few days before emergence of the larvae. A bundle of such twigs known as brood lac (**Fig. 4**) is tied to an uninfected tree on which tender new shoots are plentiful. The broodlac produces larvae which settle down on young branches of the tree. In existing practice, inoculations are done manually. The farmers climb the tree on suitable branches. Thus the process is slow and laborious.

There is need to develop suitable instrument for broodlac bundle placement so that process becomes faster and less cumbersome.

Phunki Removal

Brood lac stick left on the tree after insect emergence, is popularly known as phunki lac.

When broodlac is allowed to remain on trees even after emergence of adult of harmful insects might invade a new crop. Therefore, timely removal of phunki is necessary to prevent carryover of pests to new crops. In existing practice phunki is mostly removed from tree manually which again requires climbing on the tree. Some farmers also use inverted J shaped cutting hook mounted on a bamboo-pole (**Fig. 5**) and used for pulling down the bundles from ground level, thus avoiding the climbing the tree. As bundles fall on the ground due to impact from ground, lac encrustation gets separated from sticks partially and lost on the ground. Thus there is scope of improvement in the phunki hook so that it removes the bundle from tree branches and traps it, not allowing to fall on the ground.

Lac Harvesting

The removal of mature lac encrustation along with the stick by cutting the lac stick is known as lac harvesting. The farmers harvest the crop with the help of an axe or sharp edge knife. The use of axe for harvesting is unsuitable as it leads

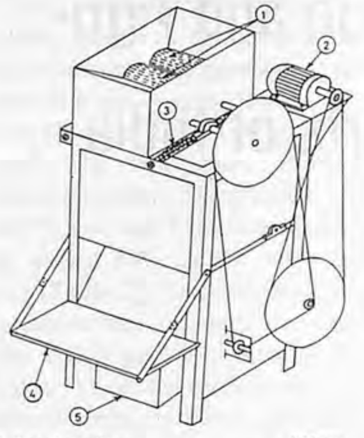
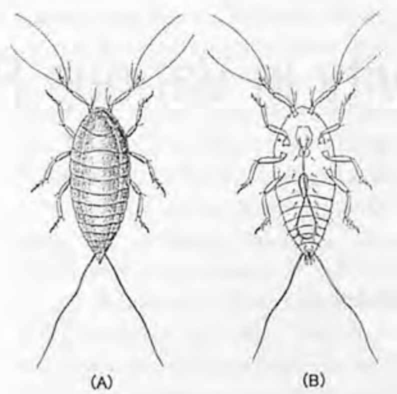


Fig.7 Lac scraping-cum-grading machine.



Appendix Fig.1 Lac insect (*Laccifer lacca, Kerr*).

Appendix Fig.2 Lac incrustation on Kusum (*Schleichera oleosa*).

to cracking or splitting the branches. Further, for use of either axe or knife farmers climb the tree which makes harvesting process slow and laborious.

Lac Scraping

Lac scraping involves removal of lac encrustation from the lac stick. Farmers scrape lac from lac sticks using traditional knives. The process is very tedious and slow. It involves sitting on the ground in a group and scraping by means of special type of knives. Lot of impurities such as sand, dirt, stick pieces etc. also find their way with the scraped lac.

A manual lac scraping machine (**Fig. 6**) has been developed by the Agricultural Engineering Department, Birsa Agricultural University, Ranchi. It consists of two disks. One disk is spring-mounted and remains stationary. The other disk is with pegs on working surface and it is driven by hand cranking handle. There is a pair of gears mounted on rotary disk shaft and hand cranking shaft. The number of teeth on the two gears are in 6:35 ratio. The gap between two disks can be adjusted with the gap adjusting lever. The machine scrapes 5 kg lac sticks in an hour and separates about 93.7 per cent lac from the lac stick. One person alone is adequate to operate the machine.

A lac scraping machine (**Fig. 7**) was developed by CIPHET, Ludhiana (Anon., 1998). The machine is capable of scraping a large amount of lac in a short time from the lac sticks of varying diameters. Further, the machine also does crushing and grading which is neither done in manual scraping nor in scraping by manual scraping machine. The machine has three sections, namely; scraping, crushing and grading section. The scraping section comprises of two specially made m.s. scraping rollers. The rollers rotate in opposite directions at a particular speed differential. The scraped lac and sticks so obtained are guided to two different outlets in the separating sections by rotor made up of 8 gauge mild steel wire wound over the mild steel rods to give it a shape of rotating screen having individual opening of 25 × 10 mm. The rotating screen or rotor thus formed doesn't allow the sticks to enter but scraped lac passes through the screen and is guided to crushing section. The crushing section consists of two crushing rollers which reduce the size of the scraped lac. The crushed lac thus obtained is passed through grading section for separating different grain sizes. The machine scrapes about 20 kg lac stick in an hour and separates about 92 per cent lac from lac stick in two passes. Two persons are required to operate the machine. The source of power to machine is 1.5 kW 3-phase A.C. motor.

Conclusions

The status of mechanization in the lac production operations needs immediate attention. Lac growing farmers are economically poor. Special attention should be given to developing equipment for such farmers to enable them to procure them at affordable price.

REFERENCES

Glover, P.M. Lac cultivation in India. Indian Lac Research Institute, Ranchi (India), 1937.

Mukhopadhyay, B. And Muthana, M.S. A monograph on lac. Indian Lac Research Institute, Ranchi (India), 1962.

Anon., Vision 2020, Perspective Plan, CIPHET, Ludhiana (India) 1998. ■■

Relationship Between Mechanization and Agricultural Productivity in Various Parts of India

by
Gajendra Singh
Professor of Agricultural Engineering
Asian Institute of Technology
Bangkok,
Thailand

Abstract

Farm power available from animate (human and animal) and inanimate (mechanical and electric) power sources was computed for whole India for the 1950-1997 period and for the year 1995-96 for major states of India representing different agro-ecological conditions. Information on cultivated area, yield and production was also compiled. The analysis of data shows that the yield is positively related to power available in both time and space, similar to relationship between fertilizer input and yield.

Introduction

India is a large country with wide agro-ecological diversity having predominance of rainfed agriculture. Farm holdings are small due to higher population density and land fragmentation continues due to 'Laws of Inheritance' and 'Hindu Succession Act'. The total land area of India is 328 Mha. An estimated 142 Mha is cultivated area of which about 55 Mha is irrigated and remainder, the 87 Mha, is rainfed. Although the share of agriculture in India's gross domestic product has declined to about 25% in 1998 from 56% in 1950 about 70% of the population still depend on agriculture for their livelihood. The population is still growing at a fast rate and will reach 1000 million in the year 2000. According to the United Nations medium scenario the population of India will be 1.33 billion in the year 2025, 1.53 billion in the year 2050, 1.62 billion in the year 2100 and may stabilize around 1.7 billion in the year 2150. Mainly due to vegetarian diet the production of 200 million tons of food grains is just sufficient to feed the present population. The biggest challenge before the agriculture sector of India is to meet the growing demand for food to feed her increasing population. With economic growth the composition of the diet is expected to include more animal products requiring higher food grains consumption per person. Assuming that the per caput foodgrain consumption will rise to 300 kg per year, India will need to produce almost 500 million mt of food grains to feed the population of 1.7 billion.

To increase food production, the productivity of land and labor need to be increased substantially which will require both higher energy inputs and better management of food production systems. The total food grain production increased from 50.8 million mt during 1950-51, to 199.3 million mt in 1996-97 and land productivity increased from 0.58 mt/ha/year to more than 2.14 mt/ha/year (**Table1**). The increase in the production of food grain was possible as a result of increased irrigation, adoption of high yielding variety seeds, higher dose of fertilizer and plant protection chemicals and increased availability of farm power. Irrigation played a major role in increasing the cropping intensity and yield. The high yielding variety seeds have been the catalysts for making other inputs cost effective. The use of certified seeds by the farmers has increased from 200,000 mt during 1970-71 to 700,000 mt in 1996-97.

The cultivated area has remained around 142 million ha during last few years. An additional area of about 52 million ha which includes fallow lands and land under pasture, tree crops and cultivable waste could be brought under cultivation. As the cost of bringing this land under cultivation would be extremely high the cultivated area is expected to remain around 140 million ha for many years in the future. To increase food production, the only option is to increase the productivity of land. This paper discusses food production in various states of India based on cropped area planted to different crops, total physical power availability, and land productivity.

Area Planted to Various Crops

The geographic area and terrain

of India vary greatly, by states. The country has been divided into 20 agro-climatic zones representing almost all kinds of agro-climates. Almost all kinds of crops are grown in India. The four states, namely; Madhya Pradesh, Maharashtra, Uttar Pradesh and Rajasthan account for almost 50% of the cultivated area (**Table 2**). Rice, the most important cereal, occupies the most area and is grown in most of the States. Wheat, the second most important cereal, is mostly grown in northern India. The cropped area under oilseeds is almost equal to the area under wheat crop. Based on cropped area pulses come next followed by millet and cotton. Other major crops grown include maize, sorghum, jute, sugarcane, potato, onions, coconut and tobacco. Based on the availability of surface and ground water the percentage of irrigated area varies from 94% in Punjab, 79% in Haryana, 65% in Uttar Pradesh and 54% in Karnataka to only 13% in Maharashtra. Accordingly, the cropping intensity also varies with a maximum of 1.80 in Punjab followed by Haryana (1.68) and Uttar Pradesh (1.49). The cropping intensity in the areas with limited water supply is very low as in the states of Gujrat (1.13), Karnataka (1.15) and Rajasthan (1.20).

Farm Power Sources

Draught Animals

Draught animals in India continue to be a major power source for field operations. In the sloppy hill regions and on small farms the draught animals will remain the main power source, besides human power. The number of draught animals, as a result of adoption of mechanical power in agriculture, is however, declining. A recently published Livestock Census report indicated that the population of draft animals has decreased from 80.9 million in 1961 to about 70.7 million in 1992, although the total bovine population increased from

Table 1. Area, Cropping Intensity, Yield and Production, 1950-97

Year	Net cropped area (Mha)	Net irrigated area (Mha)	Gross cropped area (Mha)	Cropping intensity	Area under grains (Mha)	Grain production (Mt)	Grain area/ Gross cropped area	Total (grain equivalent) production (Mt)	Yield in grain equivalent (t/ha/year)
1950	118.8	20.9	131.9	1.11	97.3	50.8	0.74	68.9	0.58
1955	126.0	22.8	142.3	1.13	110.6	66.9	0.78	86.1	0.68
1960	133.2	24.7	152.8	1.15	115.6	82.0	0.76	108.4	0.81
1965	136.7	27.8	159.3	1.16	115.1	72.4	0.72	100.1	0.73
1970	140.3	31.1	165.8	1.18	124.3	108.4	0.75	144.6	1.03
1975	140.1	34.6	169.2	1.21	128.2	121.0	0.76	159.8	1.14
1980	140.0	38.7	172.6	1.23	126.7	129.6	0.73	176.6	1.26
1985	141.5	43.2	179.2	1.27	128.0	150.4	0.71	210.5	1.49
1990	143.0	47.8	185.7	1.30	127.8	176.4	0.69	256.3	1.79
1995	142.8	53.0	188.2	1.32	121.0	180.4	0.64	280.5	1.96
1997	142.0	55.0	190.0	1.34	124.5	199.3	0.66	304.1	2.14

Table 2. Cropped Area under Major Crops in Different States, 1995-96

State	Net cropped area (Mha)	Cropped area (Mha)										Gross cropped area (Mha)	Area under foodgrains (Mha)
		Rice	Wheat	Maize	Sorghum	Millet	Pulses	Oilseeds	Cotton	Sugarcane	Others		
Jammu and Kashmir	0.73	0.27	0.24	0.30	—	—	—	—	—	—	0.27	1.08	0.88
Himachal Pradesh	0.58	—	0.38	0.31	—	—	—	—	—	—	0.31	1.00	0.85
Punjab	4.22	2.16	3.22	0.17	—	—	—	0.25	0.75	0.13	0.93	7.61	5.71
Uttar Pradesh	17.30	5.56	8.92	1.09	0.44	0.84	2.83	1.61	—	1.97	2.59	25.85	20.34
Haryana	3.58	0.83	1.97	—	—	0.58	0.42	0.61	0.65	0.14	0.80	6.00	3.99
Rajasthan	16.38	—	2.20	0.91	0.59	4.27	3.57	3.84	0.61	0.03	3.64	19.66	11.9
Assam	2.71	2.50	—	—	—	—	—	0.31	—	0.04	1.00	3.85	2.73
Bihar	7.70	5.04	2.13	0.72	—	—	0.92	0.22	—	0.13	1.48	10.64	8.99
West Bengal	5.33	5.95	0.34	0.05	—	—	0.21	0.5	—	0.02	1.72	8.79	6.57
Madhya Pradesh	19.56	5.34	4.02	0.86	0.99	0.13	5.18	5.63	0.51	0.05	1.51	24.22	17.51
Gujrat	9.29	0.57	0.51	0.38	0.32	1.09	0.84	2.92	1.41	0.16	2.31	10.51	3.75
Orissa	6.30	4.53	—	0.04	—	—	0.93	0.46	—	0.03	2.69	8.68	5.66
Maharashtra	17.94	1.52	0.70	0.23	5.56	1.66	3.31	2.56	3.07	0.58	2.99	22.18	13.27
Andhra Pradesh	11.02	3.69	—	0.33	0.89	0.13	1.61	3.14	1.06	0.21	2.32	13.38	6.89
Karnataka	10.38	1.27	—	0.37	1.98	0.4	1.52	2.62	0.67	0.31	2.79	11.93	6.86
Tamil Nadu	5.58	1.95	—	—	0.38	0.17	0.58	1.09	0.26	0.33	1.97	6.73	3.34
Kerala	2.25	0.47	—	—	—	—	—	—	—	—	2.59	3.06	0.5
Others	1.39	1.19	0.38	0.22	0.18	0.05	0.36	0.2	0.05	0.02	0.33	2.98	1.27
India	142.23	42.84	25.01	5.98	11.33	9.32	22.28	25.96	9.04	4.15	32.24	188.15	121.01

Table 3. Major Sources of Farm Power, 1950-97

Year	Animate		Mechanical						Electrical	Total power available (Mhp)
	Worker (million)	Animal (millions)	Tractor (000)	Avg. size (hp)	Power tiller (000)	Avg. size (hp)	S. P. combine (000)	Diesel engine (million)	Electric motor (million)	
1950	95.6	65.0	8	34.1	0.0	—	0.0	0.07	0.02	42.8
1955	112.4	72.0	20	34.1	0.0	—	0.0	0.12	0.05	48.8
1960	116.0	80.4	37	34.1	0.0	—	0.0	0.23	0.20	55.2
1965	120.0	81.4	63	34.1	1.5	6.5	0.1	0.50	0.50	59.9
1970	124.2	82.6	168	34.1	9.6	9.0	0.2	1.70	1.60	76.1
1975	136.2	83.4	292	34.1	17.9	9.1	0.3	2.32	2.28	88.4
1980	149.3	73.4	531	34.1	16.2	9.1	0.3	2.88	3.35	101.0
1985	165.9	72.6	810	34.2	19.6	9.4	1.5	5.40	4.33	129.5
1990	183.5	70.9	1,192	33.9	31.2	9.7	3.2	4.80	8.07	159.2
1995	199.0	65.2	1,707	35.3	55.2	9.7	4.1	5.20	11.13	195.3
1997	205.0	62.6	2,032	35.5	65.9	9.7	4.4	5.55	11.99	212.6

Note: Assumed average power of agricultural worker: 0.1 hp, draft animal: 0.5 hp, self propelled combine harvester: 85 hp, electric motor and diesel engine for irrigation pump: 5 hp.

227 to 285 million in the same period (**Table 3**). The population of draft animals is estimated at 61.5 million in 1997.

Human Labor

Human energy is predominantly used in agriculture for all operations from seedbed preparation to threshing and transport. The 1991 Census report estimated the population of agricultural workers at 187 million. The number of agricultural workers in 1997 is estimated to be about 205 million (**Table. 3**). Due to steep slope in hilly regions, human power is used for all operations.

The adoption of mechanization has not affected the employment opportunities of agricultural workers. From the analysis of the data from the Cost of Cultivation of Principal Crops in India it was found that for whole country, the use of human power in crop production per hectare increased from 723 in 1971 to 766 hours during 1991. The opportunities for skilled and semi-skilled workers increased from 5 to 23 billion man-days/year during this period. The yearly occupation reduced marginally from 117 standard days to 101 days. But increased agricultural production provided more employment in agro-processing.

Mechanical Power

Higher energy inputs for field operations are required to increase cropping intensity and to reduce 'turn around time'. Tractor, power tiller, diesel engine and electric motor have thus, supplemented the animal power. The tractors in India were introduced in the late forties by importing war surplus tractors from Europe. The number of tractors in use estimated by Jain (1971) was 8,500 in 1951 and 37,000 in 1960; all of these were imported. The tractor manufacturing started in 1961 with 880 units. This rose to 20,000 units in 1970, 71,000 units in 1980 and 140,000 units in 1990. The production of tractors during 1997 was over 255,000 units (Singh, 1999). The number of tractors in use in India at the end of 1997 was estimated to be over two million units (**Table 3**). Based on 142 Mha cultivated land, there is one tractor for each 71 hectares of cultivated land in India. The highest concentration of tractors is in northern India, especially Punjab, Haryana and western Uttar Pradesh where wheat is a major crop. Tractors are increasing rapidly in Madhya Pradesh, Rajasthan, Gujrat and Maharashtra (**Table. 4**).

The power tiller although introduced in the 1960s has not become popular (**Tables 3** and **4**). The yearly production is about 10,000 with a total population of 66,000 units only (Singh, 1999). These are main-

Table 4. Availability of Tractors and Power Tillers in Various States, 1997

State	Agriculture land (1000 ha)	Tractor		Power tiller	
		Population	Units/000 ha	Population	Units/000 ha
Jammu and Kashmir	1,014	3,700	3.7	20	0.0
Himachal Pradesh	1,010	2,200	2.2	10	0.0
Punjab	4,033	332,700	82.5	20	0.0
Uttar Pradesh	17,986	434,400	24.2	260	0.0
Haryana	3,711	233,400	62.9	20	0.0
Rajasthan	20,971	175,300	8.4	30	0.0
Assam	3,205	6,400	2.0	6,130	1.7
Bihar	10,743	74,100	6.9	740	0.1
West Bengal	5,656	16,100	2.9	17,400	2.8
Madhya Pradesh	22,111	195,100	8.9	410	0.0
Gujrat	10,292	146,500	14.2	1,710	0.2
Orissa	5,296	13,000	2.5	1,550	0.3
Maharashtra	20,925	110,800	5.3	3,150	0.1
Andhra Pradesh	14,460	100,100	6.9	3,560	0.2
Karnataka	12,321	73,900	6.0	9,230	0.7
Tamil Nadu	7,474	85,100	11.4	12,400	1.5
Kerala	1,796	7,700	4.3	5,120	2.6
Others	2,505	5,200	2.1	4,180	1.7
Total	165,509	2,015,600	12.2	65,930	0.4

ly used in the states of West Bengal, Tamil Nadu, Andhra Pradesh, Kerala, Karnataka and Assam where rice is a major crop.

Electric Motors and Diesel Engines for Irrigation Pumps

One of the major inputs adopted by the Indian farmers for modernization of agriculture is irrigation pumps. The irrigated area has increased from 21 million hectares during 1950 to 55 million hectares in 1997 (**Table 1**). The population of electric motor-operated pumps has increased from 1.6 million in 1970 to 12 million in 1997 and the diesel engine pumps from 1.7 to 5.5 million (**Table 3**). The government encouraged the farmers to have their own irrigation facilities by giving financial incentives. Presently subsidy is provided to the farmers for adoption of sprinkler and drip system under the promotion for the cultivation of horticultural crops.

Availability of Farm Power in India

The availability of farm power per unit area (kW/ha) has been considered as one of the parameters for expressing level of mechanization. During 1950 to 1997, the total farm power increased from 0.27 kW/ha to 1.12 kW/ha (**Table 5**). During this period the share of animate power declined from 98% to 24% while the share of combined mechanical and electrical power increased from less than 2% to over 75% (**Table 5**). The Use of commercial energy for farm power as diesel fuel for tractors, power tillers and diesel engine-operated pumps has been increasing consistently (**Table 6**). An actual estimate of use of diesel in agriculture is difficult to make but on an average about 9-10% of the total diesel is estimated to be used in agriculture sector, based on the rural outlets created for distribution.

The consumption of electricity mainly for electric motor-driven irrigation pumps has grown at a fast rate (**Table 6**). This is mainly due to emphasis on rural electrification by the government. During 1970-71 only 18.5% of the total villages were electrified which increased to 87% by the end of 1996. The growth in electrification was 6.9% annually. The energy generation increased by 8% annually but consumption in rural areas increased by 8.6%. In many states electricity is available for limited duration during the day. The electricity consumption by the agriculture sector increased from 10% in 1971 to about 33% of the total consumption in 1995.

During the last 50 years the farmers have made significant investment in farm power. Annual investment in agricultural implements and machines during 1997 is estimated to be over Rs 180 billion, equivalent to US $5.14 billion (Singh, 1998). The trend of farm power available during 1950-1997 is given in **Table 5**. During this period the animate power from agricultural workers and draft animals has remained more or less the same, varying between 0.26 kW to 0. 29 kW per hectare. The number of draft animals started to decline in 1975, however, the number of agricultural workers continues to increase (**Table 3**). The farm power has increased rapidly, from 0.27 kW/ha in 1950 to 1.12 kW/ha in 1997, due to increase in mechanical power, mainly from tractors, and electric motors driving irrigation pumps. All the increase in farm power in the future will be contributed by mechanical and electrical sources as animate power is estimated to remain at the present level in the near future.

There is a positive relationship between farm power available and the annual grain equivalent yield (**Figure 1**). The trend lines assuming both linear relationship and logarithmic relationship were fitted to the given data. The linear as well as logarithmic relationships fitted ex-

Table 5. Per Hectare Power Available on Indian Farms, 1950-97

Year	Net cropped area (Mha)	Farm Power Total (Mhp)	Farm Power Unit (kW/ha)	Animate Power kW/ha	Animate Power %	Mechanical Power kW/ha	Mechanical Power %	Electrical Power kW/ha	Electrical Power %
1950	118.8	42.8	0.27	0.26	98.3	0.00	1.5	0.00	0.2
1955	129.2	48.8	0.28	0.27	96.9	0.01	2.6	0.00	0.5
1960	133.2	55.2	0.31	0.29	93.8	0.01	4.4	0.01	1.8
1965	136.2	59.9	0.33	0.29	88.0	0.03	7.8	0.01	4.2
1970	140.3	76.1	0.40	0.29	70.6	0.08	18.8	0.04	10.5
1975	140.1	88.4	0.47	0.29	62.5	0.12	24.6	0.06	12.9
1980	140.0	101.0	0.54	0.27	51.1	0.17	32.3	0.09	16.6
1985	141.3	129.5	0.68	0.28	40.8	0.29	42.5	0.11	16.7
1990	143.0	159.2	0.83	0.28	33.8	0.34	40.8	0.21	25.4
1995	142.8	195.3	1.02	0.27	26.9	0.46	44.6	0.29	28.5
1997	142.0	212.6	1.12	0.27	24.4	0.53	47.5	0.31	28.2

Table 6. Use of Commercial Energy in Agriculture, 1970-95

Energy source	1970	1975	1980	1985	1990	1995
Diesel energy						
Total rural use (thousand tonnes)	153.5	527.6	1034.5	1339.7	2113.9	2462.3
For crop production (thousand tonnes)	61.4	211	413.8	535.9	845.6	985.0
Net sown area (Mha)	140.3	140.1	140	141.5	143	143.0
kg/ha	0.4	1.5	3.0	3.8	5.9	6.9
Mj/ha	18.4	63.3	124.1	159.1	248.4	289.3
Electrical energy						
Electricity, Gwh	4460	9592	14489	23422	50321	61207.8
kWh/ha	31.8	68.5	103.5	165.5	351.9	428.0
Mj/ha	114.4	246.5	372.6	595.9	1266.8	1540.7
Total (Diesel+Electricity), Mj/ha	132.8	309.7	496.7	755.0	1515.2	1829.9

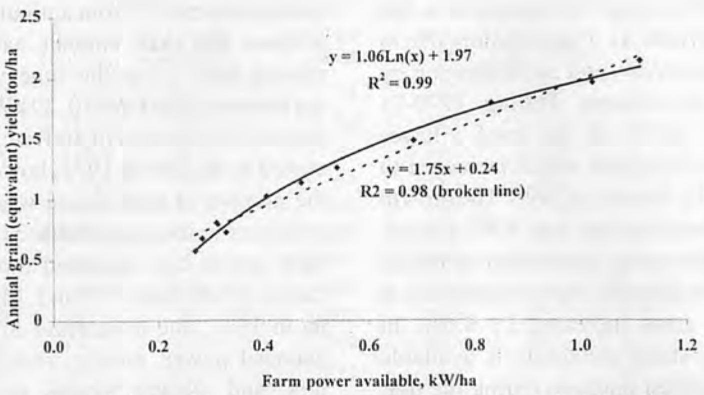


Fig. 1 Relationship between farm power and yield during 1950-97.

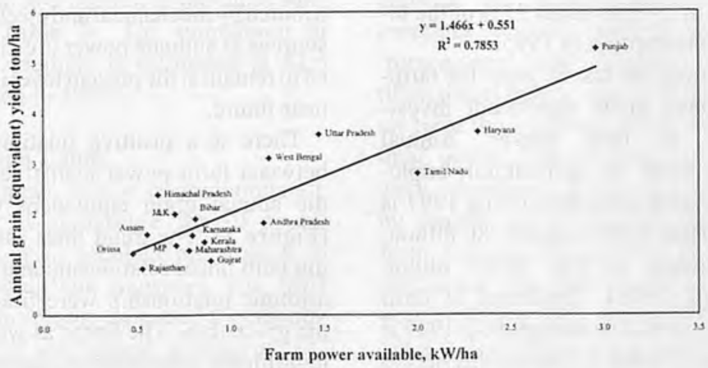


Fig. 2 Relationship between farm power available and yield in different states,1995-96.

tremely well. However, in long run, as available power increases, the logarithmic relationship will become more realistic as it follows the law of diminishing returns.

Availability of Farm Power in Different States

The availability of physical power from animate, mechanical and electrical power sources in different states of India is shown in **Table 7** and **Table 8**. The state of Punjab has the highest available power per hectare (2.96 kW/ha) followed by the state of Haryana (2.33 kW/ha). Mechanical power (including about 20% from electric motors) accounts for most of the power while the contribution of animate power in these two states is about 5 percent only. The use of electrical power, mainly for pumping irrigation water, is also very high representing about 17-20% of the total available power. This indicates a high level of mechanization in these two states. Other state with less than 15% share from animate sources is Rajasthan.

In two hilly states, Jammu and Kashmir and Himachal Pradesh and two other states, Orissa and Assam, most of the operations are done using manual tools and animal-drawn implements. In these states animate power accounts for more than 80% of the total power representing a

Table 7. Farm Power Available in Different States, 1995-96

State	Sources of physical power						Total power available (Mhp)
	Agril. labor (million)	Draft Animal (millions)	Tractor (000)	Power tiller (000)	Diesel engine (million)	Electric motor (million)	
Jammu and Kashmir	1.27	0.860	3.07	0.02	0.002	0.003	0.69
Himachal Pradesh	0.16	0.747	1.77	0.01	0.001	0.004	0.48
Punjab	3.82	0.704	318.89	0.02	0.217	0.724	16.73
Uttar Pradesh	20.96	11.092	379.03	0.23	1.851	0.783	34.23
Haryana	2.40	0.659	211.04	0.02	0.186	0.435	11.15
Rajasthan	3.74	2.646	138.74	0.03	0.501	0.504	11.63
Assam	2.22	2.998	5.88	5.56	0.004	0.004	2.02
Bihar	24.41	1.327	59.57	0.67	0.356	0.285	8.42
West Bengal	13.20	4.978	12.40	15.77	0.741	0.105	8.63
Madhya Pradesh	15.66	10.408	147.86	0.37	0.206	1.130	18.68
Gujrat	8.46	2.567	115.89	1.55	0.408	0.576	11.17
Orissa	7.71	5.073	8.60	1.41	0.016	0.069	4.06
Maharashtra	21.67	6.294	86.17	2.86	0.097	1.980	18.78
Andhra Pradesh	30.11	5.053	81.64	3.23	0.161	1.632	17.43
Karnataka	13.07	4.336	56.26	8.37	0.120	0.995	11.12
Tamil Nadu	19.98	2.363	67.30	11.24	0.293	1.568	14.98
Kerala	5.37	0.205	6.79	4.64	0.036	0.299	2.60
Others	4.770	2.891	6.11	13.93	0.004	0.032	2.45
India	199.00	65.200	1707.00	69.92	5.200	11.13	195.26

Note: Assumed average power of agricultural worker: 0.1 hp, draft animal: 0.5 hp, self propelled combine harvester: 85 hp, electric motor and diesel engine for irrigation pump: 5 hp.

Table 8. Farm Power Available, by Source 1995-96

State	Available power (kW/ha)				Percent share in available power		
	Animate	Mechanical	Electrical	Total	Animate	Mechanical	Electrical
Jammu and Kashmir	0.57	0.12	0.02	0.71	80.5	17.2	2.3
Himachal Pradesh	0.50	0.09	0.03	0.61	81.1	14.4	4.5
Punjab	0.13	2.19	0.64	2.96	4.4	74.0	21.6
Uttar Pradesh	0.33	0.98	0.17	1.48	22.3	66.2	11.4
Haryana	0.12	1.75	0.45	2.33	5.1	75.4	19.5
Rajasthan	0.08	0.34	0.11	0.53	14.6	63.7	21.7
Assam	0.47	0.08	0.01	0.56	85.1	13.9	1.0
Bihar	0.30	0.38	0.14	0.82	36.9	46.2	16.9
West Bengal	0.53	0.60	0.07	1.21	44.1	49.8	6.1
Madhya Pradesh	0.26	0.24	0.22	0.71	36.2	33.5	30.2
Gujrat	0.17	0.49	0.23	0.90	19.1	55.1	25.8
Orissa	0.39	0.05	0.04	0.48	81.6	9.9	8.6
Maharashtra	0.22	0.15	0.41	0.78	28.3	19.0	52.7
Andhra Pradesh	0.37	0.25	0.55	1.18	31.8	21.4	46.8
Karnataka	0.25	0.19	0.36	0.80	31.2	24.0	44.8
Tamil Nadu	0.43	0.53	1.05	2.00	21.2	26.4	52.4
Kerala	0.21	0.15	0.50	0.86	24.6	17.9	57.5
Others	1.03	0.20	0.09	1.32	78.37	15.09	6.54
India	0.27	0.46	0.29	1.02	26.9	44.6	28.5

very low level of mechanization. Other states with high use of animate power are West Bengal (44%), Bihar (37%), Madhya Pradesh (36%), Andhra Pradesh ((32%), Karnataka (31%) and Maharashtra (28%). In three states, namely, Kerala, Maharashtra and Tamilnadu, the use of electric motors to power irrigation pumps accounts for more than 50% of the total power. Other states with significant share of electric power use include Andhra Pradesh (0.55 kW/ha) and Karnataka (0.36 kW/ha).

The yield of selected crops in different states during 1995-96 is shown in **Table 9**. The grain equivalent yield is linearly related to the physical power availability as shown by the best-fit line with an R-square value of 0.8781 (**Figure 2**). Punjab has the maximum power availability (2.96 kW/ha) with the highest grain equivalent yield of about 5.5 ton/ha/year.

Figure 1 shows a positive relationship between power available and yields over a period of 47 years while **Figure 2** shows a similar positive relationship for different states of India during 1995-96. This shows that within the limits of data yield is positively related to power available in both time and space.

Fertilizer Input

During 1950-97, the input of nutrients from manure and compost has remained almost constant at about 8 kg per hectare, while the use of chemical fertilizers has increased from 0.5 kg/ha in 1950 to 121 kg/ha in 1997. Considering that cropping intensity in 1997 was 1.34, the fertilizer input per hectare of gross cropped area would be about 90 kg/ha. The analysis of data (**Table 10**) shows that yield has increased linearly with increase in fertilizer input (**Figure 4**). This may be true due to low levels of fertilizer input. However, as in the case of farm power, the yield is also expected to follow logarithmic relationship (law of diminishing returns) with increased use of fertilizers in future.

The fertilizer input in different states of the country during 1995-96 is given in **Table 11**. It varied from 18 kg/ha in Assam to 300 kg/ha in Punjab. The relationship between fertilizer input and grain equivalent yield in different states of country is shown in **Figure 4**. It is a positive relationship given by a straight line with R^2 value of 0.866.

Table 9. Yield of Selected Crops, 1995-96

State	Yield (ton/ha)							
	Foodgrains	Oilseeds	Cotton	Jute	Sugarcane	Potato	Onion	Coconut
Jammu & Kashmir	1.67	—	—	—	—	—	—	—
Himachal Pradesh	1.60	—	—	—	—	8.64	—	—
Punjab	3.47	0.21	0.44	—	65.30	20.51	—	—
Uttar Pradesh	1.89	0.88	—	—	60.69	20.09	11.82	—
Haryana	2.54	1.28	0.34	—	56.18	14.50	—	—
Rajasthan	0.80	0.80	0.38	—	50.39	—	—	—
Assam	1.31	0.51	—	1.67	41.51	6.81	—	—
Bihar	1.44	0.63	—	1.54	43.84	8.86	7.85	—
West Bengal	1.96	0.05	—	1.97	76.27	24.46	—	12.04
Madhya Pradesh	1.03	0.88	0.14	—	39.96	11.73	11.16	—
Gujrat	1.09	0.74	0.27	—	65.05	20.04	23.37	—
Orissa	1.20	0.53	—	1.14	58.40	9.74	7.60	5.22
Maharashtra	0.87	0.78	0.16	0.26	80.44	—	12.10	—
Andhra Pradesh	1.69	0.97	0.26	1.42	71.00	—	15.57	13.68
Karnataka	1.26	0.67	0.21	—	79.56	11.94	5.59	5.20
Tamil Nadu	1.92	1.46	0.22	—	100.99	21.63	10.82	10.10
Kerala	1.94	—	—	—	—	—	—	6.02

Figure 3 shows a positive relationship between fertilizer input and yield over a period of 47 years while **Figure 4** shows a similar positive relationship for different states of India during 1995-96. This shows that within the limits of data yield is positively related to fertilizer input in both time and space.

Use of Farm Machines

In India farmers use a variety of hand tools, animal drawn implements and power operated equipment. The most common hand tools are sickle, spade, hand hoe, shovel, crowbar, pickaxe and rake. Many small machines also use human muscle power like seeders, sprayers, pedal operated paddy thresher, hand maize sheller, groundnut decorticator, hand cleaner, grader and chaff cutter.

The most common animal-drawn implement is traditional animal drawn country plough with a very low capacity (30-40 h/ha). Depending upon field condition and crop requirement, 3 to 6 passes are made for land preparation. Cultivator and disc harrow cover 2-3 times more area than a country plow. Tine cultivator, disc harrow, pegtooth harrow, puddler, spring tine harrow and leveler operated by animal and tractor are becoming popular. It is estimated that more than 12.7 million steel plows, 6.5 million cultivators, 3.9 million disc harrows and 6.3 million animal drawn puddlers were in use in 1995-96. Custom hiring of tractor drawn-equipment is a common practice.

Line sowing not only saves seed but also facilitates regulated application of fertilizer near root zone and the use of mechanical weeders. Bamboo pipe and funnel in the traditional sowing devices has been replaced by steel or plastic pipe and funnel. Seed drill and seed-cum-fertilizer drill operated by animal and tractor have been developed and are being manufactured to suit specific crops and regions for sowing/planting of wheat, paddy, coarse cereals, pulses and oilseeds. Planters have been developed for maize, potato and groundnut crops.

For paddy transplanting manual, power tiller and engine operated rice transplanters are undergoing multi-location testing and evaluation. Sugarcane planting is not only arduous but also time consuming. Tractor operated semi-automatic sugarcane planters are already under commercial manufacture. Tractor drawn sugarcane set cutter-cum-planter has also become available recently.

Weed control in irrigated and rainfed agriculture during rainy season is a serious problem. The "khurpi" is the most versatile hand hoe for removal of weeds but it takes 300-700 man-hours to cover one hectare. Ergonomically designed long handle weeders (wheel hoe and peg type weeders), reduce this weeding time to 25-110 hours. Bullock and tractor operated weeders and cultivators are also used for weed control.

The crops need protection from pests and diseases. Different designs of low cost hand operated sprayers and dusters are commercially available for application of plant protection chemicals. Spraying in cotton, paddy, sugarcane, fruits and vegetables, oilseeds and pulses is a common practice. Due to harmful effects of pesticides integrated pest management (IPM) approach is being promoted to reduce harmful effects.

The sickle, spade and hand hoe are the major tools for harvesting and digging. These are easily available at low cost in the villages but their output is low. Self-sharpening serrated sickle has been developed which requires less frequent sharpening. Reapers operated by engine, power tiller and tractor have been

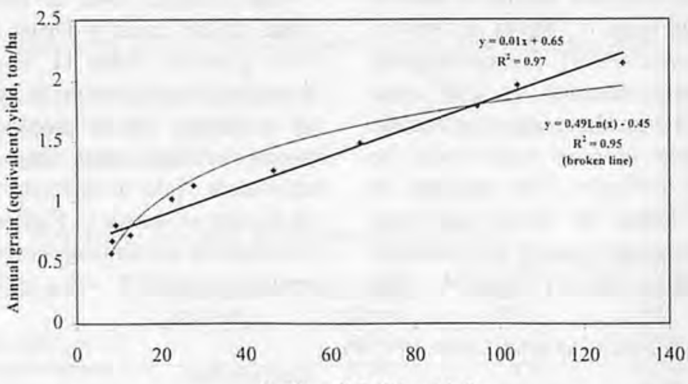


Fig. 3 Relationship between fertilizer input and yield, 1950-97.

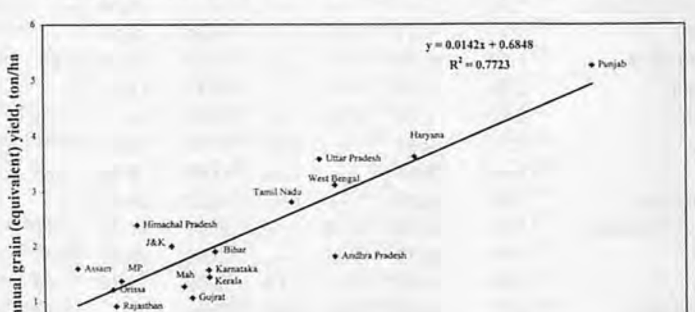


Fig. 4 Relationship between fertilizer input and yield, 1995-96.

developed and introduced for harvesting wheat, paddy, soybean, ragi and mustard.

Traditionally, threshing of wheat and barley has been done by bullock trampling which is arduous and time consuming. The mechanical threshers of varying size are being manufactured which not only thresh the grain but also provide good quality straw for the animal feed. The population of threshers was estimated to be more than 2.2 million in 1995-96. More than 80% of wheat, barley, gram, soybean, sorghum and pearl millet crops are estimated to be threshed by mechanical powered threshers mostly using custom hire services.

Tractor-operated and self-propelled combine harvesters are commercially manufactured in India. About 700-800 combines are sold annually. Combine harvester with track type traction device is also manufactured in India mainly for the paddy crop. The combine harvesting of wheat, paddy and soybean has been accepted by the farmers in regions with labor shortage and to reduce turn around time for planting taking next crop. These are available on custom hire basis. Paddy crop is easy to thresh by beating but losses are high. Pedal operated paddy threshers reduce drudgery. These have become popular in Eastern India. Raspbar type paddy threshers cause less breakage to paddy stem and have become very popular in Andhra Pradesh, Tamil Nadu, Karnataka and Kerala.

Table 10. Annual Input of Plant Nutrients, 1950-97

Year	Cultivated area (Mha)	Chemical fertilizer			
		N (000 ton)	P (000ton)	K (000ton)	kg/ha
1950	118.8	58.7	6.9	—	0.55
1955	126.0	107.5	13.0	10.3	1.04
1960	133.2	210.0	53.1	29.0	2.19
1965	136.7	574.8	132.5	77.3	5.74
1970	140.3	1,487.0	462.0	228.0	15.52
1975	140.1	2,148.6	466.8	278.3	20.65
1980	140.0	3,678.1	1,213.6	623.9	39.40
1985	141.5	5,660.8	2,005.2	808.1	59.89
1990	143.0	7,997.2	3,221.0	1,328.0	87.74
1995	142.8	9,822.8	2,897.5	1,155.8	97.16
1997	143.0	11,738.0	4,109.0	1,471.0	121.1

Table 11. Available Fertilizer Input, 1995-96

State	Fertilizer input (kg/ha)			
	N	P	K	Total
Jammu and Kashmir	59.5	9.6	0.7	69.8
Himachal Pradesh	42.6	4.4	3.9	50.9
Punjab	241.9	53.9	3.7	299.5
Uttar Pradesh	122.5	24.0	4.1	150.6
Haryana	164.2	37.4	0.9	202.5
Rajasthan	29.7	9.2	0.3	39.2
Assam	8.7	2.0	7.4	18.2
Bihar	72.5	15.3	5.7	93.5
West Bengal	96.0	36.6	26.3	158.9
Madhya Pradesh	27.8	12.7	1.8	42.2
Gujrat	59.4	17.2	4.5	81.1
Orissa	27.7	5.6	4.4	37.7
Maharashtra	48.4	18.5	9.6	76.6
Andhra Pradesh	107.7	38.2	13.0	158.9
Karnataka	51.7	23.6	14.9	90.2
Tamil Nadu	74.9	25.4	35.1	135.4
Kerala	38.8	19.1	32.6	90.5
Others	43.9	9.9	4.6	58.4
India	69.1	20.4	8.1	97.6

Future Thrust in Mechanization

Draught animals and agricultural workers may remain the major source of farm power in many states. The use of mechanical power for tillage, irrigation, harvesting, threshing and transport will continue to increase, including through custom hiring services. Tools for horticulture and forestry may have to be introduced through importation, which should lead to local manufacturing. The present available designs for farm machines are adequate but will require improvement in their quality through material substitution and manufacturing.

Machines for transplanting/planting of paddy, sugarcane, vegetables and trees are yet to be developed to a level of perfection acceptable to the farmers. Machines for application of manure and liquid Nitrogen fertilizer are not available in India. Handling and application of biogas slurry is also manual. These require special attentions of R&D institutions.

Thresher technology is well accepted by the farmers. Combine harvesting for cereal crops is becoming popular in many states and the industry is capable of meeting the demand. Alternative straw handling and disposal technology may have to be developed and promoted as burning of straw is creating environmental pollution and farmers are loosing valuable animal feed material.

Maize, sorghum, cotton, sugarcane, potato, peanut, sunflower, safflower, soybean, pulses are predominantly harvested manually. Large and commercial farming of these crops may require alternative harvesting and handling machinery. Similarly harvesting of fruits could be mechanized through selective importation, keeping in view the local availability of agricultural workers and drudgery in operations.

Indian industries are capable of meeting domestic requirement of tractors, diesel engines, electric motors and power tillers. The fuel economy and comfort/safety of tractors need to be improved. In the future, the use of tractor will expand in operations like sowing, spraying, interculture, harvesting, agro-forestry, tree harvesting, plantation, land development, excavation for irrigation and drainage channels, etc. Some of these will require introduction of specialized tractors.

Irrigation pumps are operated by electric motors or diesel engines. While quality of electric motor is satisfactory, there is need to introduce efficient light diesel engine through joint ventures or importation to begin with.

Concluding Remarks

Table 12 summarizes the availability of major inputs for crop production and grain equivalent yield in different states of India. Cropping intensity is mainly dependent on water availability through the year. Rainfall distribution through the year as well as the percent area irrigated in different seasons can reflect water availability. The state of Punjab in spite of low annual rainfall of 555 mm concentrated mainly during three months (July, August and September) but with 94 percent area irrigated has a cropping intensity of 1.80. While the states of Kerala and Assam with very high annual rainfall but with limited area under irrigation have low cropping intensity. Due to water availability throughout the year farmers in Punjab are able to use high yielding varieties and high dose of fertilizer. Assisted by high amounts of available power they are able to get high yields.

The average annual yield of rice in India is about 2 mt/ha. However, Punjab has already achieved an annual yield of 5.3 mt/ha. If the whole of India can achieve this level of annual yield the grain production, of over 500 million mt would be enough to feed a population of 1.7 billion as mentioned earlier. However the yields obtained in many countries for a single crop are as high as 7 mt/ha for rice in Korea, 7.6 mt/ha for wheat in France and U.K. and 9.3 mt/ha for maize in Italy. With over 30,000 scientists and an extensive education, research and extension system in place, India should not have any difficulty in feeding its fast growing population. Provided there is a strong POLITICAL WILL.

Table 12. Major Inputs and Annual Grain Equivalent Yield, 1995-96

State	Annual rainfall (mm)	% Irrigated area	Power (kW/ha)	Fertilizer (kg/ha)	Cropping intensity	Grain equivalent yield (ton/ha)
Jammu and Kashmir	617	40.0	0.71	69.8	1.48	2.01
Himachal Pradesh	494	13.1	0.61	50.9	1.71	2.40
Punjab	555	93.7	2.96	299.5	1.80	5.26
Uttar Pradesh	837	64.7	1.48	150.6	1.49	3.58
Haryana	494	78.6	2.33	202.5	1.68	3.63
Rajasthan	421	29.3	0.53	39.2	1.20	0.93
Assam	1449	27.9	0.56	18.2	1.42	1.61
Bihar	1024	44.3	0.82	93.5	1.38	1.91
West Bengal	1355	24.7	1.21	158.9	1.65	3.11
Madhya Pradesh	1021	25.2	0.71	42.2	1.24	1.38
Gujrat	609	31.1	0.90	81.1	1.13	1.08
Orissa	1123	28.6	0.48	37.7	1.38	1.23
Maharashtra	920	13.4	0.78	76.6	1.24	1.28
Andhra Pradesh	594	40.8	1.18	158.9	1.21	1.83
Karnataka	802	24.9	0.80	90.2	1.15	1.58
Tamil Nadu	950	53.6	2.00	135.4	1.21	2.81
Kerala	1927	19.3	0.86	90.5	1.36	1.45
Total	880	38.3	1.02	97.6	1.32	1.96

REFERENCES

Agricultural Statistics at a Glance'. Directorate of Economics & Statistics, Department of Agriculture & Co-operation, Ministry of Agriculture, Government of India, New Delhi, 1998.

1992 Indian Livestock Census'. Directorate of Economics & Statistics, Department of Agriculture & Co-operation, Ministry of Agriculture, Government of India, New Delhi, 1998.

Statistical Outline of India 1997-98'. Tata Services Limited, Mumbai, India, 1998.

B.K.S. Jain. 'Production of Agricultural Machinery in India'. Paper presented at the Mechanisation Workshop held at the International Rice Research Institute, Manila, Philippines, 1971.

Gajendra Singh. 'Energy in Agriculture'. Paper presented at the International Agricultural Engineering Conference, Bangkok, Thailand,

Gajendra Singh and R. S. Doharey. 'Tractor Industry in India'. Paper presented at the Annual Meeting of the Club of Bologna, November 14-16, 1998, Bologna, Italy. ■■

ABSTRACTS

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

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Improving the Potential of Wheat-drilled Direct in Rice Tract: **Abdul Razzaq**, Senior subject matter specialist (Engg.), Adaptive Research Farm, Sheikhupura, PAKISTAN. **Abdul Karim** (late), Assistant Research Officer, Adaptive Research Farm, Sheikhupura, PAKISTAN.

In clay loam and loam soil, straight and cross patterns of direct drilling of wheat were tested under zero tillage condition in comparison with the conventional method of sowing after land preparation. Under zero-tilled condition, straight drilling was found suitable on loam soil as it significantly in \creased wheat yield by 4.61% over clay loam. Registering a significant increase of 8.09% in wheat yield, 11.45% higher net income and BCR of 2.71. Cross drilling was observed as an efficient technology in zero tilled clay loam soil. Drilling of wheat in conventionally tilled soil increased its yield although it was significantly higher in clay loam than loam. The economic performance was low compared to zero tillage method.

901

Failure Patterns of Electrical System of Tractors: **Er. Pawan Kr. Tuteja**, Agril. Engineer Krishi Vigyan Kendra,Ambala (Haryana), 133 104, INDIA. **Er. Rajender Kumar**, ADO (FI), Deputy Director Agriculture, (Govt. of Haryana), SIWANI (BHIWANI) 125021, INDIA. **Er. S. C. L Premi**, Associate Prof. Dept. of Farm Power & Machinery, CCS HAU 125 004, INDIA. **Er. V.P. Behl**, Associate Prof. Dept. of Farm Power & Machinery, CCS HAU 125 004, INDIA.

The field data regarding the number of breakdowns in different time between failure for 50 tractors (Ford 3600) was recorded in Hisar districts of Haryana (India), and analysed.

It was observed that the mean to down time of electrical system was 42.42 hrs. The active mean time to repair for the electrical system was 2.44 hrs. The MTBF for electrical system was 956.8 hrs. The battery of the electrical system was most failure prone. The reliability and failure rate at MTBF was 0.410 and 0.001, respectively. The maximum chance of failure of electrical system lies in the range of 400-1200 hrs.

906

Fabrication and Evaluation of Pyramid Type and Conical Type Solar Stills: **G. Amuthan**, College of Agricultural Engineering, Tamil Nadu Agricultural University, Coimbatore - 641 003, INDIA. **P. Subramanian**, Same.

Two models of solar stills viz., pyramid type (glass covered) and conical type (UV stabilised polyethylene covered) were fabricated with the same base area of 1 m^2 and surface area of 1.25 m^2. They were tested with different salt concentrations of inlet water viz., 60, 100, 200 and 300 gm/lit with 2.5 cm height of water in the basin. The stills were evaluated in terms of distillation rate, efficiency of performance and production cost per litre. The glass covered still yielded2.80 to 3.50 litres/m^2/day whereas the polyethylene covered model yielded 0.90 to 1.40 litres/m^2/day. The efficiency of distillation based on base area and cover area varied, respectively, from 37 to 46 percent and 30 to 34 percent (for glass covered still) and 15 to 23 per cent and 12 to 18 per cent (for UV stabilised polyethylene covered still). The cost of the glass covered pyramid type solar still was about $25 and the cost of polyethylene covered conical still was about $15. The production cost was estimated at $0.57/100 litres and $2.08/100 litres for the glass covered still and polyethylene covered still, respectively.

912

A Decade Study on the Status and Constraints of Agricultural Mechanization in Central, India: **Dr. Atul Kumar Shrivastava**, Asst. Professor, Dept. of Farm Machinery and Power, College of Agricultural Engineering, J.N.K.V.V., Jabalpur-482004 (M.P.) INDIA. **Dr. C. L. Thakur**, Assoc. professor, Same. **S. P. Shrivastava**, Tech. Asst. Dept. of Soil Science, College of Agriculture, J.N.K.V.V., Jabalpur-482004 (M.P.)INDIA.

This paper deals with the identification of the constraints on the basis of agro climatic conditions, in the use of agricultural implements and machinery in the state of Madhya Pradesh, India. The state was categorized as rainfed and level of mechanization is low. The responsible factors for the low level of mechanization are technical, economical and social. Based upon production constraints and extension or research gap, attempts were made to suggest various recommendations to overcome these problems. ■■

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☆ ★ ☆

Drying Technology in Agriculture and Food Sciences

(USA)

by Arun S. Mujumdar

Preface

Drying is one of the most cost-effective means of preservation of grains, crops and foods of all varieties. This technique has been practiced since time immemorial. From both energy and environmental viewpoints as well as the global requirement to feed the growing population, it is important that the drying technique and technology be improved to reduce spoilage and enhance quality of the product. Much has been accomplished over the past two decades as far as understanding and development of drying technologies are concerned for foods and agro-products. This book is a compilation of selected invited and refereed articles covering topics of contemporary interest in a global sense. Future volumes will cover topics of related interest.

The focus of the book is on agricultural and food drying technologies. It starts off with a discussion of the thermodynamic properties of moist grains, followed by extensive overview of an important topic in drying kinetics of grains and food viz. moisture diffusivity values. For drying calculations it is very important to know the hygrothermal and quality parameters of grains, which is the theme of the following chapter. The next two chapters deal with the interaction between quality and drying characteristics. Drying of enzymes and forage are important current topics of interest in the food and agricultural industries which are the themes of the following three chapters. For energy savings coupled with higher quality product, heat pump dryers have become increasingly important drying technology for heat sensitive materials; this is covered in an extensive review chapter. Finally, the last two chapters focus on new developments of potential interest to the food and agricultural industrial sectors. Microwave drying has found a niche market already although much remains to be done in terms of R&D before this technology becomes commonly accepted. The final chapter provides a global overview of innovative drying technologies covering developments in the agricultural and food sectors but also other industrial sectors; awareness of advances by other sectors can trigger improved technologies for the agricultural and food sectors in the future.

It is my hope that this book will stimulate the interest of the readers to apply the information provided here and also to develop new areas for R&D and thus make definitive contributions to this truly inter-disciplinary and all-pervasive field It is my pleasant duty to thank the authors and referees for their time and effort. Also, I want to acknowledge with thanks the assistance provided by Sakamon Devahastin and Felipe Osorno in compiling this book in a format suitable for publication in a short time. This work was accomplished during the transition period of my move from McCill University, Montreal, Canada to the National University of Singapore, Singapore. Even under normal circumstances this is a major undertaking; without the quality of help I was fortunate to receive from the aforementioned individuals, this project could not have, seen the light of the day any time soon. Any weaknesses and flaws that remain are entirely

Arun S. Mujumdar
Singapore

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Lecturer, Dept. of Agric. Engineering and Land Planning, Botswana College of Agriculture., Private Bag 0027, Gaborone, BOTSWANA TEL(267)-3650120,FAX(267)-328753,E-mail:amahapat@temo.bca.bw

Mathias Fru Fonteh
Asst. Professor and Head, Dept. of Agric. Engineering, Faculty of Agriculture, University of Dschang, P.O. Box 447, Dschang, West Province, CAMEROON TEL(+237)-45-1701/1994,FAX(+237)-45-2173/1932, E-mai:m.f.fonteh@camnet.cm

Edward A. Baryeh
Professor, Dept. M.H.T.C.,ESIE, BP311 Bingerville, Côe d'lvoire

Ahmed Abdel Khalek El Behery
Agric Engineering Research Institute, Agricultural Reserch Center, Nadi El-Said St. P.O. Box 256, Dokki 12311, Giza, EGYPT

Ali Mahmoud El Hossary
Senior Advisor to the Ministry of Agriculture and Chairman of (AGES)-Agengineering Consulting Group, Ministry of Agriculture - P.O.Box 195 Zamalek 11211 Cairo, EGYPT TEL00-202-335-9304,FAX00-202-3494-132

B.S. Pathak
Project Manager, Agric. Implements Research and Improvement Centre, Melkassa, ETHIOPIA

David Boakye Ampratwum
Part-Time Lecturer, Agricultural and Food Engineering, University of Ghana, Legon, GHANA(Mailing Address: Associate Professor, Dept.of Agric. Mechanization, Sultan Qaboos University, College of Agriculture, P.O. Box 34,Al-Khod 123, Muscat, Sultanate of Oman)

Richard Jinks Bani
Lecturer & Co-ordinator, Agric. Engineering Div., Faculty of Agriculture, University of Ghana, Legon, GHANA

Israel Kofi Djokoto
Senior Lecturer, University of Science andTechnology, Kumasi, GHANA

David Kimutaiarap Some
Professor, Deputy Vice-chancellor, Moi University, P.O. Box: 2405, Eldoret, KENYA

Karim Houmy
Professor and head of the Farm Mechanization Dept., Institute of Agronomy and Velerinary Medicine II, Secteur 13 Immeuble 2 Hay Riad,Rabat, MOROCCO. Tel:212-7-68-05-12, Fax: 212-7-775801,E-mail:houmy@maghrebnet.net.ma

Joseph Chukwugotium Igbeka
Professor, Dept. of Agricultural Engineering, Univ. of Ibadan,, Ibadan, NIGERIA TEL(+234)-2-8101100-4,FAX(+234)-281030118, E-mail:Library@Ibadan.ac.ng

E.U, Odigboh
Professor, Agricultural Engg Dept., Faculty of Engineering, University of Nigeria, Nsukka, Enugu state, NIGERIA TEL(+234)-042-771676,FAX(+234)-042-770644 : 771550,E-mail:MISUNN@aol.com

Kayode C. Oni
Senior Lecturer, Dept. of Agric. Engineering, University of Ilorin, P.M.B. 1515 Ilorin, NIGERIA

Umar B. Bindir
Lecturer and Team Leader of Engineering Section, Dept. of Agriculture, The University of Technology, P.M.B. Lae, PAPUA NEW GINIA

N.G. Kuyembeh
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Abdien Hassan Abdoun
Member of Board, Amin Enterprises Ltd., P.O. Box 1333, Khartoum, SUDAN

Amir Bakheit Saeed
Assoc. Professor, Dept. of Agric. Engineering, Faculty of Agriculture, University of Khartoum, 310131 Shambat, SUDAN TEL+249-11-310131

Surya Nath
Senior Lecturer, Dept. of Land Use and Mechanization, University of Swaziland, , P.O. Luyengo, SWAZILAND TEL(268)-5283464,FAX(268)-5185276, E-mail:Nath@agric.uniswa.sz

Abdisalam I. Khatibu
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-AMERICAS-

Hugo Alfredo Centrángolo
Full Professor and Director of Food and Agribusiness Program Agronomy College Buenos Aires University, Av. San Martin4453, (1417) Capital Federal, ARGENTINA TEL(+54)-11-4524-8041/93,FAX(+54)-11-4514-8737/39,E-mail:hcetrang@correo.secyt.gov.ar

Irenilza de Alencar Nääs
Professor, Agricultural Engineering College, UNICAMP, Agricultural Construction Dept.,P.O. Box 6011, 13081 -Campinas- S.P.,BRAZIL TEL(+55)-19-7881039,FAX(+55)-19-7881010, E-mail:irenilza@agr.unicamp.br

A.E. Ghaly
Professor, Biological Engineering Deparment Dalhousie University, P.O. Box 1000, Halifax, Nova Scotia, B3J2X4, CANADA TEL(+1)-902-494-6014,FAX(+1)-902-423-2423,E-mail:abdel.gahaly@dal.ca

Edmundo J. Hetz
Professor, Dept. of Agric. Engineering, University of Concepción, Av. V.Méndez 595, P.O. Box 537, Chillan, CHILE TEL(+56)-42-216333,FAX(+56)-42-275303,E-mail:ehetz@udec.cl

A.A. Valenzuela
Irrigation Professor University of Concepción, Chillan, CHILE TEL(+56)-42-223613,FAX(+56)-42-221167

Roberto Aguirre
Associate Professor, National University of Colombia, A.A. 237, Palmira, COLOMBIA TEL(+57)-572-2717000,FAX(+57)-572-2714235, E-mail:ra@palmira.unal.edu.co

Omar Ulloa-Torres
Professor, Escuela de Agricultura de la Region, Tropical Humeda(EARTH), Apdo. 4442- 1000, San Jose, COSTA RICA TEL(+506)-255-2000,FAX(+506)-255-2726, E-mail:o-ulloa@ns.earth.ac.cr

Hipólito Ortiz-Laurel
Head of Agric. Engineering and Mechanization Dept. / Postgraduate College, Iturbide 73, Salinas de Hgo, S.L.P., C.P. 78600, MEXICO TEL(+52)-496-30448,FAX(+52)-496-30240

S.G. Campos Magana
Leader of Agric. Engineering Dept. of the Gulf of Mexico Region of the National Institute of Forestry and Agricultural Research, Apdo. Postal 429, Veracruz, Ver. MEXICO


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-ASIA and OCEANIA-

Shah M. Farouk
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Mohammed A. Mazed
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Wang Wanjun
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S.R. Verma
Prof. of Agril. Engineering, College of Agril. Engg., Punjab Agricultural University, Ludhiana - 141004, INDIA TEL(+91)-(0)161-401960/439,FAX(+91)-(0)161-400945,E-mail:srverma@pau.chd.nic.in

Sarath Ilangantileke
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Soedjatmiko
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Mansoor Behroozi-Lar
Professor, Agr. Machinery, Ph.D, Tehram University Faculty of Agriculture, Karaj, IRAN TEL(+98)-21-8259240,E-mail:mblar@chmran.ut.ac.ir

Jun Sakai
Professor Emeritus, Kyushu University, 2-31-1 Chihaya, Higashi-ku, Fukuoka city, 813, JAPAN TEL+81-(0)92-672-2929,FAX+81-(0)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, Agricultural 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

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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

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l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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