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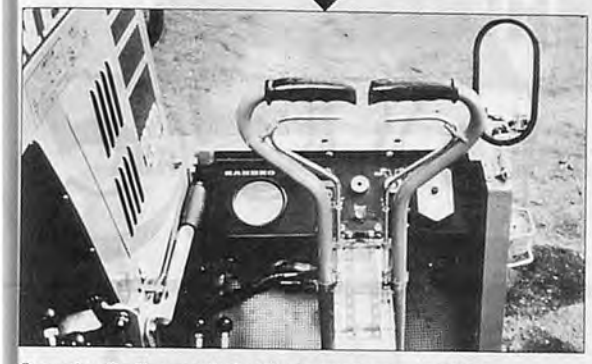
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Editorial

China Revisited

I had the good fortune of visiting the Peoples' Republic of China recently after a long while. And my immediate reaction to the observations I gathered was that: China is happening! Indeed, it would seem that the "Sleeping Giant" is not sleeping anymore when the following observations are taken into account:

1. Agricultural mechanization has progressed rapidly in recent years as evidenced by a high national average density of nearly 2.8 hp/ha in 1984 and the widespread use of 4-wheel tractors in farms and as transport facility;
2. Newly-built farm houses that dot the country-side and the suburbs of Shanghai can no longer hide the obvious high standards of living and prosperity being enjoyed by the farmers;
3. Some 1.5 million ha of paddy fields have recently been converted into fish farms considering that the country has reportedly achieved rice self-sufficiency level by 1984;
4. The high yields of maize and other grains in the northeastern part of the country is reputed to have reached the stage or threshold of export levels;
5. Soybean and cotton yields have equally reached unprecedented highs in recent years; and
6. Elsewhere, agriculture as a whole is growing at a rate faster than ever before.

The preceding gains are indicative of the Government's serious and bold stroke to give high priority to the welfare of the farmers who constitute some 80 percent of the total population, including the giving to farmers the right to utilize land and other resources as they see fit, hence motivate them to be enterprising and productive.

For another, Chinese agricultural machines are currently priced rather low and within the reach of most farmers as the Government controls the price of steel by about half the price in the international market. Add to this the fact that labor in China is plentiful and relatively cheap.

But even as the political system of the country is not as liberalized as those prevailing in other countries, the economic system, in comparison, has been liberalized enough as to provide the impetus necessary for growth and development. Given another 10 years, it may come as surprise to many that China will be ready to join the rank of developed countries.

These observations are intended to be shared with policy-makers in the developing and less developed countries because they are by themselves lessons of experience: be it in pricing farm machines realistically, emancipating the farmers from poverty and providing them with proper incentives to raise productivity levels, or, the impact of the current development efforts on the entire socio-economic system of the country.

Yoshisuke Kishida
Chief Editor

July, 1985
Tokyo

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Notes on Agricultural Machinery Manufacture in the Developing Countries of Asia



by
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Abstract

The purpose of this article is to elaborate on some aspects of agricultural machinery manufacture in the developing Asian countries. The background explains the need for agricultural mechanization, defines the various types of agricultural mechanization, and summarizes the status of the agricultural machinery industry in the developing Asian countries. The paper further discusses typical features of the agricultural tool and machinery industry, and based on size and technology employed, classifies the industry in four categories. Because of the predominant manufacture in cottage, small- and medium-scale industries, the industries' common problems often relate to absence of economies of scale. Various government policies which affect the agricultural machinery industry are discussed such as attractive incentives for foreign investors, protection of domestic industry, emphasis on appropriate technology and labor-intensive manufacture, and public-sector enterprise. The article recommends that local manufacture should be encouraged whenever technically and economically feasible. Efficient and realistic government support policies are considered to be a precondition to succeed. Additional topics covered include assessing realistically the demand for tools, implements and machinery, and a broad strategy for the manufacture of major groups of tools, implements and machinery, including sub-contracting and regional collaboration.

Background

Most Asian countries are primarily agrarian societies in which agriculture is the main source of wealth. Thus, for these countries an increase in agricultural productivity is a primary requirement for rural and overall economic development. In addition, by the end of this century world population may surpass 6 billion, against 4.3 billion today. A substantial increase in agricultural productivity will be required to meet the future food needs of this increasing population. Historically, productivity increases are linked with technological change including the introduction of mechanization. To enhance agricultural productivity, increase in farm power will be required especially in areas with rural labor shortage or potential for high cropping intensities. In addition, there is also a need for mechanization technology which is complementary to improved cropping system (e.g. pumpsets and pesticide applicators).

Agricultural mechanization is defined as the utilization of improved hand tools, implements for draft animals and mechanically-powered (motorized) machinery for agricultural land development, production, harvesting, and on-farm processing. Consequently, three major levels of mechanization technology are to be considered: hand-tool technology, animal-draft technology and mechanical-power technology. In addition, within each level different degrees of sophistication are available. For example, a 8 hp single-axle tractor and a 65 hp two-axle tractor are both "tractors", but they are very different in terms of investment, productivity and need for institutional support such as training, operation and maintenance. Consequently, there is a large variety of mechanization inputs which may be manufactured.

Only in India are all mechanization inputs manufactured within the country. In Thailand, the Philippines, the Republic of China, and the Republic of Korea, a major part of the farm tools, implements and machinery demanded by farmers is also being made locally. Other Asian countries have followed this strategy to a various degree but many countries still import

much of the agricultural machinery needed, especially the more sophisticated items.

Manufacture of Mechanization Inputs

Many Asian countries have established industrialization policies to accommodate, or even actively attract, foreign investors. These foreign investments are considered important or even necessary for the much needed technology transfer. However, with the exception of two-axle tractor manufacture, this process of industrialization and transfer of technology hardly applies to the agricultural tools, implements and machinery manufacture sector of most Asian countries. Usually, manufacture of agricultural machinery has emerged from small rural workshops rather than from established industrial enterprises. These small family enterprises neither need nor had access to modern management methods and know-how. When demand for their products increased, they merely increased the labor force in their workshop. For example, in Thailand manufacturers of single-axle tractors and threshers may produce substantial volumes but still operate more or less as a village workshop. In most cases, no blue prints are used, modern design criteria are not applied and many of their product designs have evolved through "trial-and-error." The Agricultural Engineering Department of the International Rice Research Institute (IRRI) has contributed significantly in some countries to improve this situation by providing blueprints, training and advisory services.

Different levels of know-how and investment in manufacture technology are required depending on the quality, type and sophistication of agricultural tools, implements and machinery to be produced. Manufacture is usually classified in cottage or household-, small-, medium-, and large-scale industries, i.e., based on number of persons employed and/or production volume. For some purpose, it is more appropriate to classify the agricultural machinery manufacturing industry according to the production technology used because medium-size manufacturers may use similar production processes as small manufacturers or workshops. A good example of this is the single-axle tractor manufacture in Thailand whereby a large manufacturer in the Central Plain (employing over 100 workers) uses the same production technology (i.e., cutting and welding) as the small village workshops (with less than 10 workers) which turn out only few tractors a year.

In order to assess the technical capability of the industry, the manufacture of mechanization inputs may be classified based on the technology employed (i.e. traditional, intermediate or modern techniques) even though this concept is inherently ambiguous as there are numerous other criteria (e.g. investment per employee).

(i) Production by village artisans (or cottage industry) – In many developing countries, these artisans are the main producers of hand tools, simple hand-operated machines and draft-animal implements. Typically, these items are without moving parts and require only simple *traditional village blacksmith technology*. Know-how is transferred within the local community, investment is very small and cash is only required for labor, scrap iron and steel, and charcoal;

(ii) Production in workshops – Here, draft animal and simple tractor soil tillage implements, machinery (e.g., threshers), and simple single-axle tractors are produced using *traditional and some intermediate technology*, i.e., cutting and welding. Standard components (e.g., fasteners, sprockets, roller chain and bearings) and prime movers (petrol and diesel engines) are obtained from outside, either through import or from other manufacturers. Investment in workshop tools and machinery is generally low and production is labor-intensive. Single-axle tractor and threshers manufactured in Thailand and the Philippines are examples of this manufacture category even though in terms of number of persons employed, they may be considered large-scale industries.

(iii) Intermediate manufacture process – This is the early stage of a real manufacture process: i.e. turning out large quantities of identical items. Products usually include hand tools, animal- and tractor-drawn soil tillage implements and simple machinery. Simple processes and operations, such as casting, stamping, die-pressing and forging may be employed but usually few machine tools are required given the type of tools and machinery produced. Cutting, welding and assembling may still be major activities and, therefore, production may still be labor-intensive. Press-shop machinery, including dies, may take a major share of the capital investment. Skilled labor is required for making patterns and dies and for starting up and maintaining production machinery. Standard components (e.g. fasteners) are usually purchased from outside suppliers. Examples of this type of industry is the manufacture of hoes by Boma Bisma in East Java, Indonesia, and tractor implements by Sayyed Machinery in Pakistan.

(iv) Advanced manufacture process – In this case, modern (automated) mass production technology such as casting, pressing, forging, cutting, shaping and assembly-line are employed to produce agricultural tools, implements and ma-

chinery. This type of industry is characterized by high capital investments, high volume output and high labor productivity. Products may vary from hand sprayers to two-axle tractors. This level of agricultural machinery industry has been established in, for example, the Republic of Korea, the Republic of China, and India.

In addition to the above classification, a distinction has to be made between *assembling* using imported parts and components, and the *actual manufacture*. In several countries, the more sophisticated machinery may be produced in assembly plants from CKD (Completely Knocked Down) kits, using various levels of local content. Examples are the production of two-axle tractors (e.g. Massey Ferguson in Pakistan, Fiat in Republic of Korea) and single-piston diesel engines in Indonesia, Thailand and Bangladesh. To many countries, tractors are shipped partly disassembled (e.g. only wheels and front axle are to be assembled while locally-made tyres may be fitted) to save on shipping costs, but this should not be considered as assembling operation since it does not or hardly add value in the technical sense.

Small is not always Beautiful

With few exceptions, most agricultural implements and machinery production in Asian developing countries takes place in small- and medium-scale industries employing traditional and intermediate technology. Because of these common features, the agricultural machinery industry has some similar dominant problems in most developing Asian countries (Gifford and Rijk 1980):

(i) The small- and medium-scale industries have insufficient turnover to justify economic investments in modern production technology, research and development, design engineering, marketing and management. Consequently, the small-scale manufacturer may find himself caught in a vicious circle because he is unable to compete economically and/or technically with imports, even when realistic incentives are established.

(ii) Demand for agricultural machinery is usually highly seasonal. This causes an extra financial burden and management problem for the manufacturer, especially when he has not diversified his products.

(iii) Small-scale industries have to rely for research on government institutes and universities. In most developing countries, however, the research is inefficient or the linkage between researcher and manufacturer is not very well developed, or does not even exist.

(iv) Small manufacturers often have difficulties in obtaining the right quality material or components. They cannot efficiently import directly because of small quantities involved.

(v) Most countries do not have strict quality control standards. The better but more expensive products may not be able to compete with the cheap, but poorly-manufactured products since farmers often cannot judge quality of products which are new to them.

Government Policies and Strategies Affecting Machinery Manufacture

The above suggests that many of the difficulties in the machinery manufacture industry are related to economies of scale. However, absence of economies of scale is only one aspect and may in some cases be a result rather than the cause. In some countries government policies put limitations on the establishment of industries or the manufacture of agricultural machinery. This may hamper the development of an efficient agricultural machinery industry.

Many Asian countries have established policies which favor local manufacture over import. Special incentives may have been granted in order to encourage foreign manufactures of (small) engines, power tillers, two-axle tractors, and other machinery to establish joint ventures for local assembling operations with the agreement that gradually the locally-manufactured content will be increased. This approach to industrialization has been advocated as one solution for exchange of know-how and industrial development. The manufacture of diesel engines, power tillers, two-axle tractors and combine harvesters in the Republic of Korea, Taiwan and in India are typical examples of this joint-venture approach.

In some cases, however, protective policies and incentives keep inefficient local machinery manufacturers in business by creating an artificial advantage over cheaper and better quality imported products. For example, several governments allow only CKD imports in order to create jobs in the assembling operation. However, in many cases prices for CBU (completely built-up) equipment of the more sophisticated technology (e.g. engines, power tillers and two-axle tractors) may be lower than the costs of locally assembled equipment because of limited demand and, therefore, absence of economies of scale for assembling and high overhead costs. An assembling plant that puts together 10 tractors a day is a far cry from an automated line that turns out that many per hour. Even in spite of a large existing local demand, the local assembly of single-piston diesel engines in Thailand, Indonesia, and Bangladesh with progressive substitution with local content can apparently not compete with CBU import without strong government protection. For example, in Thai-

land the locally assembled single-piston diesel engines were estimated to be at least 30% more expensive than similar CBU imported engines (Rijk 1984). Recently, it was stated that the manufacture of motorcycle engines in Thailand (using high levels of local content) may increase its costs by 3-5 times since the present domestic market (300 000 units/year) is not big enough (The Nation 1984). Similarly, the manufacture of stationary gasoline engines in the Philippines to substitute for imported Briggs & Straton engines, which are widely used in coastal fishing operations and for powering agricultural machinery, is not considered economically viable by local manufacturers. Also the Philippine car manufacture industry (despite the government-ordered restructuring under the Progressive Car Manufacturing Program) can hardly survive given the annual demand of 30 000 to 40 000 cars and its cost price compares unfavorably with imported units. It is hard to see how local manufacture or assembly of standard-type two-axle tractors for only the domestic market is feasible in the majority of the Asian countries since most countries have an annual demand of less than 2 000 units.

Also, the gradual substitution with local content has not been very satisfactory in several countries and usually lags substantially behind original targets. In most cases, the actual substitution is much lower than originally planned for reasons related to higher cost and/or low quality and, therefore, a reluctance to increase the local content. In cases where the substitution with local content appears significant, it has to be realized that it is not unusual to measure this in weight rather than value. Local manufacture of the fly wheel, the crank (starting) handle, the (wooden) engine base may quickly add to a significant percentage of total engine weight but these parts represent little value. From casting a fly wheel, it is still a long way to go to produce the fuel injection system or other precision components. In many countries, for sophisticated power technology the trend is strongly towards the import of ready to use machinery (PICIC News 1981) and, to serve as an example, assembly of standard-type two-axle tractors in Thailand and the Philippines has been discontinued several years ago.

Nevertheless, there are cases where local assembly with gradual substitution by local content has been successful. Because of the rather large number of annual sales (over 7 000 units) as compared to most other Asian countries (less than 2 000 units), Millat Tractors in Pakistan is an example of successful local assembly of two-axle tractors with high local content. This latter example resembles the experience in this sphere from Japan, India, the Republic of Korea and Taiwan.

Over-protection of import substituting industries or limiting domestic competition in the agricultural machinery manufacture industry through licensing may not only be a heavy burden for the economy but may also delay industrial and technological development. A classic example is the Indian car industry. India and Japan began making cars at about the same time but whereas Japan managed to establish a large and highly competitive car manufacturing industry geared to the world market, India's protected car manufacturers still produce the same original model which is obsolete in terms of performance, design and manufacturing technology and, consequently, the Indian car is not in demand in the world market. Also the Republic of Korea, which started car manufacture much later than India has already become a significant automotive exporter with over 35 000 units exported in 1984. Government interference could be the explanatory factor behind retarded development of the Indian car industry which now has to bring in Japanese car manufacturers to set up modern plants in India.

Two other examples of government interference in India are the production of centrifugal pumps up to 4 inches which has been reserved for the small-scale manufacturer and the Tractor Control Order. Some tractor brands can only be bought with a license as their demand is higher than actual production, but because of the government's "Tractor Control Order" (which includes price control), the manufacturers do not find it attractive to increase production (Gifford and Rijk, 1980). One of the consequences may have been that because of this control, export of the Indian-made tractors has been insignificant.

Too much emphasis on alternative technology may be another reason why agricultural machinery manufacture stagnates. The appropriate technology and labor-intensive manufacturing approach advocates that small village workshops should be able to produce agricultural machines. The IRRI designed single-axle tractor is an example of this appropriate technology philosophy. However, the fact that, for example, the single-axle tractor produced in a small village workshop is priced lower than an imported power tiller is not necessarily a justification for this approach. First of all, the single-axle tractor represents a different technology and has less capabilities than the power tiller, e.g. it has no power-take-off and is not suitable for transport. Secondly, it should be analyzed how much this simple single-axle tractor would cost if it is produced in factories which have benefits of economies of scale (e.g. by using stamping, pressing and

casting technology) rather than in a small workshop employing traditional less efficient production technology (i.e. cutting and welding). In addition, manufacture in many small workshops contributes to proliferation of makes and models, which may have negative consequences for quality and inter-changeability of spare parts and implements. In the Philippines, some manufacturers claimed that the "appropriate" design philosophy with regard to manufacture of agricultural machinery in small workshops attracted many fly-by-night producers during the boom in demand (as a result of World Bank Agricultural Credit Projects) but prohibited the establishment of an efficient sustainable industry which would not only produce for the local market but also could have captured the regional Asian market.

In Indonesia, the manufacture of agricultural tools and implements has been encouraged in the small-scale sector. Several small factories make hand sprayers using low-quality material and technology, resulting in an expensive and poor quality final product. Consequently, preference is given to imported sprayers (Rijk, 1979).

The fact that modern production technology is superior is frequently overlooked in the effort to promote alternative technology and labor-intensive industries. The industrial revolution, or technology revolution, has not only increased the capital/labor ratio and labor productivity in the production processes but also greatly improved quality of the final product and reduced cost of production (e.g. reduction in material costs – steel implements may in some countries already be cheaper than wooden ones – and energy consumption in the manufacturing process). Therefore, labor-intensive or intermediate production methods may be economically and technically inferior because modern manufacturing technology reflects not only a capital investment, but also a certain quality and efficiency (innovation). This may explain that single-axle tractors, the manufacture of which does not require high precision or quality control, are all locally-manufactured (except for the engine) in Thailand. On the other hand, manual-operated pesticide applicators, of which some important parts require a high level of precision and quality, are still imported in Thailand in substantial quantities since the local manufacturers apparently cannot compete in quality and price with imported sprayers.

Industrial development policies that focus on using abundant supply of cheap labor have an appeal to labor surplus countries, but unless that abundant human resource is supported by efficient management techniques, modern technology, financing and marketing, it may hamper industrial development in the long run. Also, modern production technologies and methods are not necessarily capital-intensive per unit output. For example, the use of templates, jigs, fixtures, casting technology, pressing and stamping machines, does not require very high capital investments but does considerably improve labor productivity and the quality of final products. Medium- and large-scale operations will also enable the higher overhead costs of better management, marketing and work organization which will in return increase productivity and quality.

In relation with the above, existing manufacturing plants are sometimes transferred from the industrialized nations to the developing countries. The rationale behind this is that although the product (e.g. tractor) may be technically outdated for the western market, since it is less sophisticated, it is considered more appropriate for the farmer in the developing country. There are two reasons to be careful about in this approach. Firstly, the country may have too small a domestic market to obtain attractive advantages of economies of scale but export is not feasible since the outdated product may not be in demand in the world market. (The previous example of the Indian car manufacture industry is illustrative for this phenomenon.) Secondly, as indicated earlier, the outdated plant does not incorporate the latest innovations and is, therefore, less efficient and may result in higher unit production costs than the latest imported designs.

At the same time, despite their concerns about increasing unemployment which in some countries has favored production of agricultural machinery in labor-intensive small-scale enterprises, developing countries may also have adopted policies which have a bias towards capital intensive production technology which is sometimes too advanced (e.g. highly automated) and compares economically unfavorable with less capital-intensive production technology. For example, distorted exchange rates, artificial low interest rates, low or even zero tariffs encourage the importation of modern manufacturing machinery. Such machinery is considered to be sound collateral and consequently, the banking system often favors this type of investment. Labor management problems may also encourage capital investment rather than employment intensive production technologies.

In some countries, public enterprises may be involved in the manufacture and distribution of agricultural machinery, e.g. the Agricultural Tool Factory in Nepal and the diesel engine manufacture by Bangladesh Steel and Engineering Corporation in Bangladesh. However,

public enterprises in developing countries all put a great claim on a scarce resource whose availability is limited within its government administration: i.e. managerial talent, combined with technical and administrative expertise. In many developing countries, the public sector is unable to obtain adequate qualified managerial staff because of certain built-in limitations such as low wages, frequent transfers, and a bureaucratic promotion system. Even the private sector in developing countries suffers often from the lack of qualified managerial skills but has more options to eliminate this constraint (e.g. paying higher wages, employing expatriates). Inefficiencies in public enterprises may be most effectively solved by selling manufacturing facilities to the private sector. This would not only improve their performance but also reduce demand on the limited managerial skills within the government.

In some countries, public enterprises may be involved in the manufacture and distribution of agricultural machinery, e.g. the Agricultural Tool Factory in Nepal and the diesel engine manufacture by Bangladesh Steel and Engineering Corporation in Bangladesh. However, public enterprises in developing countries all put a great claim on a scarce resource whose availability is limited within its government administration: i.e. managerial talent, combined with technical and administrative expertise. In many developing countries, the public sector is unable to obtain adequate qualified managerial staff because of certain built-in limitations such as low wages, frequent transfers, and a bureaucratic promotion system. Even the private sector in developing countries suffers often from the lack of qualified managerial skills but has more options to eliminate this constraint (e.g. paying higher wages, employing expatriates). Inefficciencies in public enterprises may be most effectively solved by selling manufacturing facilities to the private sector. This would not only improve their performance but also reduce demand on the limited managerial skills within the government.

It must be realized that when the agricultural machinery industry is inefficient because of erroneous and expensive industrialization policies, farmers have to pay the resulting higher prices for machinery. On the other hand, supported by efficient government policies, Taiwan and the Republic of Korea have been able to enter the world market with their products successfully. This suggests that the manufacturing sector should be properly supported by appropriately formulated policies and incentives and protections should be economically justified rather than being a bonus for inefficient production methods of obsolete technology. Also, government involvement should be in the form of stimulating the private initiative rather than controlling the investors' activities. The previous examples of policy flaws usually occur because policy makers are unable to consider all consequences of generalized policy for specific products, and because policy makers often work in isolation from the technical experts.

Assessing Realistically the Demand for Mechanization Inputs

Agricultural ministries are concerned about the utilization of agricultural machinery while the ministries of industry are interested primarily in their manufacture. In most developing countries, no formal linkage exists between these two ministries. For products with no export market, industrial production planners may have to rely on the agricultural planners to establish production capacity in balance with the expected demand. Absence of agricultural machinery demand data make it difficult to plan manufacturing capacity, although import statistics may show the demand for certain tools and machinery (e.g. hand sprayers and hoes). Machinery demand projections must be based on sound and realistic procedures, otherwise, wrong investments in manufacturing capacity are made. For example in India, based on agriculturists' recommendations, an investment for a total annual production of 40 000 power tillers was made. Actual sales, however, have been only 2 000/year since the limited technical capability and the high price of the power tillers did not make them attractive to the farmer (Gifford and Rijk, 1980). Such costly mistake may be made when the demand analysis is based on too limited information or wrong assumptions.

Three different types of "demands" for agricultural machinery have been considered in the developing countries (Rijk, 1983):

(i) The theoretical demand is usually based on an academic exercise (forecast) which determines how many units can be "placed" and whereby the criteria are only technical. For example, number of tractors required assuming a recommended power input of 0.5 hp/ha. Prognoses based on only such criteria usually have proved to be very erroneous.

(ii) The actual demand by the used (e.g. farmer) is based on his own technical, financial and other considerations (e.g. prestige) and may be created or stimulated by extension, demonstration, training, etc.

(iii) The effective demand is the proportion of the *actual demand* which will be satisfied. The difference may be created by factors such as import restrictions, shortage of supply, limitations on distribu-

tion and maintenance facilities, absence of suitable financing arrangements (credit).

These demand concepts are somewhat controversial since they are a departure from the usual economic concept of "notional" and "effective" demand, whereby "notional" demand is considered to be the speculative, imaginary or theoretical demand. The introduction of the above three demand concepts are a result of poorly executed demand/marketing studies rather than suggesting that a good marketing study/demand forcast does not take into account the above situations. The reality is, however, that comprehensive studies to analyze future mechanization needs and demands are hardly, if ever, made.

Price distortions, inefficiencies and better alternative opportunities for investment or other preferences for the individual, etc., may create a substantial gap between the "theoretical" demand and "actual" or "effective" demand. The "actual" demand may be sometimes real but because of infrastructural and institutional constraints or policies (e.g. import ban on power tillers in Bangladesh) this demand does not (yet) become effective (Rijk, 1983). The *effective demand* is a realistic basis for projecting the short- and medium-term demand for mechanization inputs and subsequent planning for agricultural machinery manufacture capacity. In the longer term, this demand can be stimulated by extension, training, change in government policies and availability of institutional support (e.g. credit).

Some Broad Strategy Recommendations

General Guidelines

Important goals of developing countries are related to industrialization for export and import substitution. Local manufacture also ensures that tools, implements and machinery are more likely to suit the country's requirements from the technical and economic points of view. It also warrants improved supply of spare parts, repair and maintenance facilities, especially if the machinery is produced in rural areas. Therefore, it must be encouraged that agricultural tools, implements and machinery be manufactured locally whenever technically and economically viable. The experience shows that some countries have been highly successful in local machinery manufacture whereas others following a similar approach have failed. Analyses suggest that a first step on the road to success seems to be that proper and realistic strategies, combined with adequate and realistic government support policies are needed as pre-condition for the successful establishment and further development of the mechanization input industry, whether it is for import substitution, export or a combination of the two. Also, from the experience in the Republic of Korea and Taiwan, it is clear that in order to manufacture sophisticated power technology, joint ventures with existing foreign manufactures are necessary, at least in the initial years of establishment and production.

Given the size of the Asian agricultural sector and its level of investment in agricultural mechanization already at present, increased efforts to develop the agricultural machinery manufacture industry are fully justified. Depending on the individual country, the following broad guidelines may be applicable:

(i) Agricultural hand tools and implements which manufacture is labor-intensive and requires only low levels of investment, know-how, and management, and which is not affected by economies of scale, is most suitable for production in Asian countries, not only for the local market but also for export. To this group of mechanization technology belong all hand tools, hand-operated implements, animal-draft implements and most conventional tractor-drawn tillage implements presently in use in Asia.

(ii) In addition to (i), the hand-tools are usually most economically produced by local artisans using scrap steel, while the animal-drawn and conventional tractor-drawn tillage implements could be produced in local workshops, employing simple cutting and welding technology.

(iii) Tools and machinery manufacture which requires high quality in terms of precision and durability (e.g. manually-operated pesticide applications or P.T.O. driven implements) may need substantial investments in manufacturing technology and, therefore, requires medium-scale to large-scale operations, or and efficient system of sub-contracting and quality control.

(iv) Other sophisticated machinery such as engines, power tillers and two-axle tractors can only be competitively produced in large quantities and require high levels of management and know-how. The need for a large production volume usually means that the country be able to secure a place for their product in the world or regional market. There may already be heavy competition in the world market from established manufacturers which suggests that careful analyses are required before investments are made.

Increase in Sub-contracting

Some of the problems associated with small-scale industry may be overcome if manufacturers would cooperate in order to obtain advantages of economies of scale (e.g., purchase of raw material, organizing promotional fairs). In most of the Asian countries, how-

ever, no significant tradition exists in cooperation among private manufacturing sector and this cooperation may be difficult to stimulate. A more successful approach might be the production of components in smaller industries and concentrate the assembly in a larger factory, similar to, for example, the practice in Japan and with Millat Tractors in Pakistan. This also facilitates inter-changeability of parts and makes repair and maintenance easier.

Regional Collaboration

Regional cooperation in the manufacturing industry would be beneficial in order to achieve economies of scale. Also, the sophisticated mechanization machinery which is designed to meet requirements of the high income countries is not always the most appropriate choice for developing countries. For example, many tractor makes are now sold with complicated hydraulic systems. These systems are usually not needed in developing countries and require well-trained mechanics, special oils, and specialized repair and maintenance facilities. Also, as a result of the sharp increase in fuel prices, a new generation of tractors may be expected soon with complicated fuel-saving injection systems which will be more difficult to repair and maintain in rural areas and may give trouble with poor quality and contaminated fuel. However, most manufacturers consider their sales to developing countries too small to adjust their designs to the conditions in developing countries. Such problems may be overcome if the developing countries are willing to cooperate in the design and production of machines which are more suited to their own needs. However, experience with ASEAN complementary manufacturing programs (e.g. diesel engines) and the Asian Utility Vehicle Manufacture Program show that this strategy is hard to implement successfully.



Fig. 1 Investment in workshop machinery is generally low and production is labor-intensive.

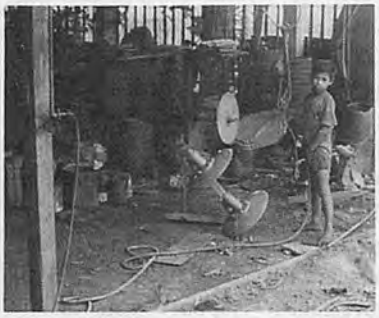


Fig. 2 In may developing countries, the agricultural machinery producer does not use blueprints, employs unskilled labor, and has no quality control.



Fig. 3 Usually, manufacture of agricultural machinery has emerged from small rural workshops rather than from established industrial enterprises.



Fig. 4 In Thailand, manufacturers of tractors may produce substantial volumes but still operate more or less as a village workshop.

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A Stationary Threshing Machine: Design, Construction and Performance Evaluation



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Abstract

Threshing process of grain crops may be accomplished mechaincally using stationary threshing machines or grain combines. In Egypt, stationary threshers are preferable over the combines for economical reasons. Stationary threshers also accumulate the straw in stacks which is considered to be an advantage since the straw must be saved for future uses.

A tractor-operated stationary threshing machine was designed, fabricated and tested with wheat crop. The effect of the cylinder-concave design on the machine performance was investigated. The performance criteria of the machine were determined.

Introduction

Harvesting and threshing of grain crops in Egypt involves hand-cutting with the sickle and threshing by a simple threshing disc implement, operated by animals. This implement consists of several metal discs fitted on a group of shafts that are supported by a wooden or steel frame and drawn by animals. Other threshing equipment available now to the Egyptian farmer are mechanically operated stationary threshing machines and grain combines.

The existing economical structure of the Egyptian agriculture and the small size of farms make the use of grain combines uneconomical. On the other hand, the use of the disc threshers for harvesting wheat crops results in an annual grain loss of 400000 t over the amount lost due to the use of stationary threshing machines. Furthermore, threshing process that required 4 days using the disc implement may be accomplished in less than 2 hours using mechanically operated stationary threshers (Ghaly, 1973).

The present study was, therefore, initiated to design, fabricate and test a tractor-operated stationary threshing machine. Both the cylinder and concave were considered as potential design parameters. The machine was tested with wheat, the most important crop in Egypt. Wheat also requires more power for threshing than any other grain crop due to chopping of straw. The experimental work was confined to the determination of the performance criteria of the machine.

Objectives

The main objectives of this study were:

1. To design, fabricate and test a tractor-operated stationary threshing machine; and
2. To evaluate the performance criteria of the machine as measured by machine capacity, power consumed in the threshing-chopping process, length of straw, total seed losses and total seed damage.

Experimental Equipment

The experimental equipment used in this study is presented in **Fig. 1**. With reference to this figure the following are the descriptions of the various components.

Threshing Machine

A stationary threshing machine (**Fig. 2**) was designed and constructed. The machine consists of a power unit (for testing purpose), a threshing-chopping cylinder and two concaves of different design; all supported by a rectangular steel frame which is carried by four corner wheels.

A diesel engine of 30 hp mounted on the machine frame was used to operate the threshing-chopping cylinder. A clutch-gear box assembly was used to connect-disconnect the power from the diesel engine to the threshing unit and to set the

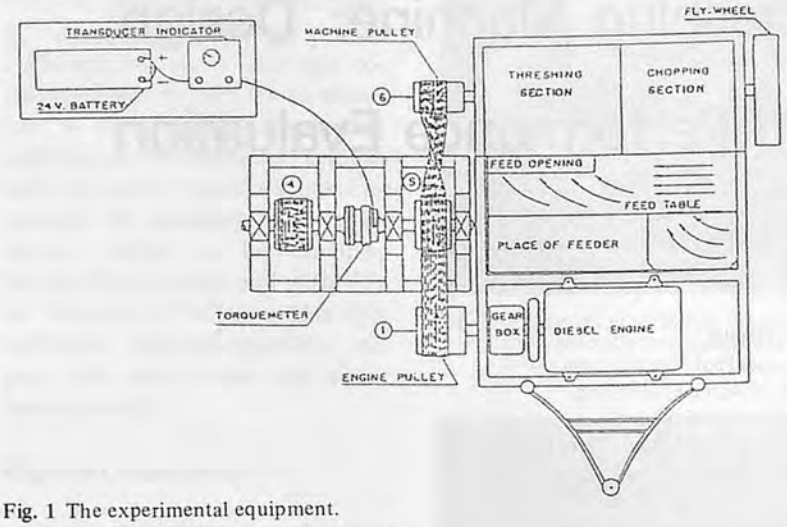


Fig. 1 The experimental equipment.

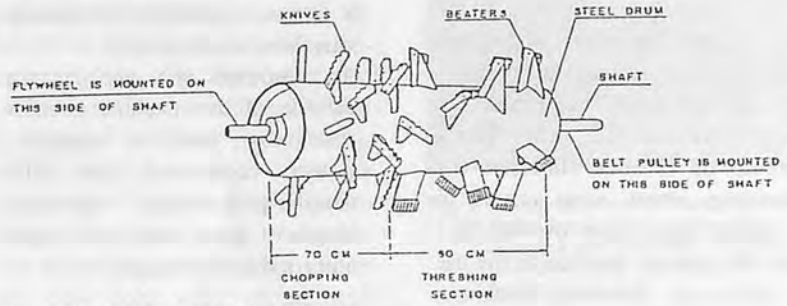


Fig. 3 The threshing-chopping cylinder.

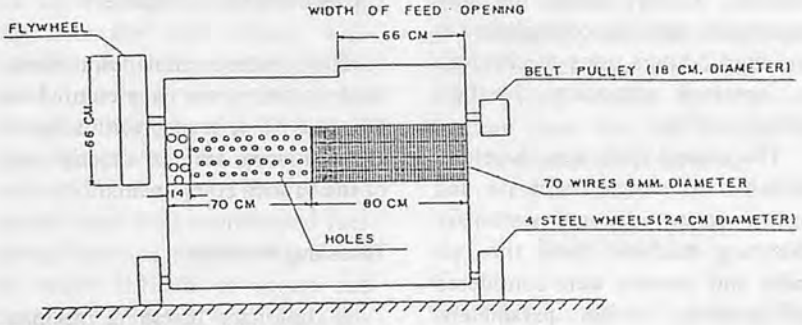


Fig. 4 The threshing and chopping concaves.

required cylinder speed. The power is transmitted from the power source to the threshing unit via belt and pulleys.

The threshing-chopping cylinder was made of 32.6 cm diameter and 150 cm long closed steel drum, fitted on a steel shaft as shown in Fig. 3. The shaft rotates in two ball bearings mounted on the sides of the machine frame. A 65-kg cast iron flywheel was mounted on one side of the shaft while a cast iron pulley of 18 cm diameter was mounted on the other side of the shaft. Threshing was accomplished by means of 12 beaters welded onto the circumference of the drum in 4 rows (3 beaters in each row), covering an axial distance of 80 cm. A replaceable corrugated piece of cast iron was bolted at the edge of each beater. Chopping of straw was accomplished by means of 36 toothed knives bolted to 12 steel plates (three knives on each plate). The plates are welded onto the circumference of the drum in 4

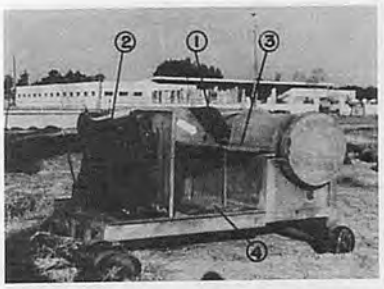


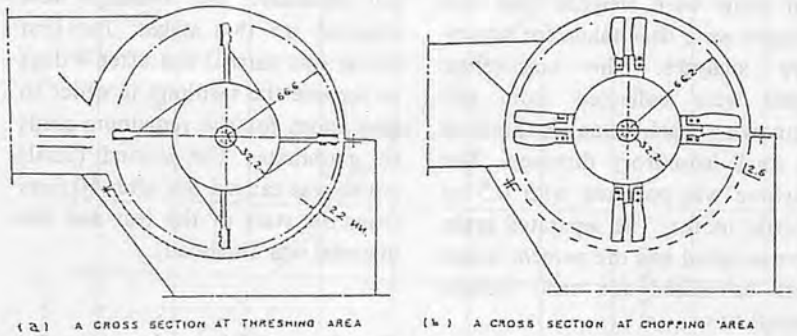
Fig. 2 The stationary threshing machine. 1. feeding opening; 2. diesel engine; 3. feed table; 4. wooden platform.

rows (3 plates in each row), covering an axial distance of 70 cm. The 4 rows of beaters and knives were inclined to the drum axis with an angle of 20° in order to promote spiral (axial) motion of the crop. As a result of the axial motion, separation of the crop would take place under the threshing section and chopping of straw would be accomplished under the chopping section. This would distribute the torque on the threshing-chopping cylinder and provide higher separation efficiency under the threshing section.

A concave made of 70 steel, 6 mm diameter equally spaced wires was fitted underneath the threshing section of the cylinder, covering an axial distance of 80 cm. Another concave with round holes was fitted underneath the chopping section, covering an axial distance of 70 cm. These concaves are shown in Fig. 4. The threshing and chopping sections were separated by metal plates so that material fallen under each section could be collected and analyzed separately.

The tips of the beaters rotate in a circle of 66.6 cm diameter with a cylinder-concave clearance of 2.2 cm, under the threshing section. The tips of the knives rotate in a circle of 66.2 cm diameter with a cylinder-concave clearance of 2.6 cm, under the chopping section. Cross-sections in the threshing-chopping cylinder at the threshing and chopping areas are shown in Fig. 5.

The dimensions and other speci-



(a) A CROSS SECTION AT THRESHING AREA (b) A CROSS SECTION AT CHOPPING AREA

Fig. 5 Cross-sections of cylinder and concave.

Table 1 Specifications of the Stationary Threshing Machine

Item	Value
Diameter of the threshing/chopping drum	32.2 cm
Length of threshing/chopping drum	150.0 cm
Axial distance of the threshing section	80.0 cm
Axial distance of the chopping section	70.0 cm
Diameter of the circle made by the beaters' tips	66.6 cm
Diameter of the circle made by the knives' tips	66.2 cm
Clearance between the tips of the beaters and concave	2.2 cm
Clearance between the tips of the knives and concave	2.6 cm
Diameter of the driven pulley	18.0 cm
Width of the driven pulley	25.0 cm
Diameter of the flywheel	66.0 cm
Width of the feed opening	66.0 cm
Height of the feed opening	26.0 cm
Diameter of the ground wheels	24.0 cm
Weight of the flywheel	65.0 kg
Weight of the machine	2 000.0 kg

fications of the threshing machine are presented in **Table 1**.

Torquemeter

A strain gauge type torquemeter shown in **Fig. 6** was used to measure the torque on the driving shaft of the machine. The meter was constructed at the National Institute of Agricultural Engineering, Silsoe, England. The meter was mounted at the middle of a steel shaft between 2 pulleys of 32 cm diameter each. The shaft rotates in 4 ball bearings mounted on a steel structure which was bolted to a heavy concrete block. The strain gauges in the meter were electrically connected to a transducer indicator, the dial of which gives a reading proportional to the instantaneous torque being transmitted. The strain gauges measure torsional strain. According to Richardson *et al* (1959) and Kepner *et al* (1978) strains caused by temperature, thrust or bending do not affect the measurement of torsional strains. Two batteries of 12 volts each were used to supply the electric power needed for the system. The torquemeter was calibrated before and after the experiments according to the operating manual.



Fig. 6 The strain gauge type torque meter.

Experimental Procedure

The wheat crop used in this study was obtained from the wheat field of the Experimental Station of the Faculty of Agriculture at University of Alexandria. Some characteristics of the wheat crop are shown in **Table 2**. At the time of harvest, the wheat field was free of weeds and had perfectly standing plants with grain that had evenly ripened. Harvesting was done during May while the threshing program was carried out during June and July. During this period, there were no rainy days and the weather was hot and uniform from one day to another.

The crop was harvested manually using the hand sickle, collected in bundles and then transported by trailers to the working area. The harvested crop was stored in a large heap. The heap was covered with a

Table 2 Some Characteristics of Wheat Crop (Giza 155) Used in the Study

Sample	Plant length (cm)	Weight of 100 seeds (g)	Weight of sample (g)	Straw in sample		Seeds in sample	
				(g)	(%)	(g)	(%)
1	136.0	3.81	126.90	81.81	64.46	45.09	35.54
2	130.0	4.06	130.00	82.50	63.46	47.50	36.54
3	135.0	3.99	127.80	81.00	63.38	46.80	36.62
4	117.0	3.69	124.92	80.00	64.04	44.92	35.96
5	130.0	4.27	124.08	79.90	64.40	44.18	35.60
6	133.0	4.53	124.50	81.05	65.10	43.45	34.90
7	129.0	3.92	131.00	82.90	63.28	48.10	36.72
8	129.0	4.25	128.40	81.20	63.24	47.20	36.76
9	135.0	4.37	126.80	80.80	63.72	46.00	36.28
10	125.0	4.42	125.50	80.30	63.98	45.20	36.02
$\bar{x}$	129.0	4.13	126.99	81.15	63.91	45.84	36.09
s	5.4	0.26	2.16	0.95	0.78	1.48	0.58
CV	4.15	6.29	16.62	1.17	1.22	3.23	1.61

large canvas to avoid the losses in moisture content of the crop.

A large scale was used to weigh 30 kg of wheat bundles, an amount required for each experimental run. Three workers picked up the wheat bundles from the large heap and placed them on the scale platform. Then, they left the weighed wheat bundles from the scale and placed them on the ground beside the threshing machines. This material was fed into the machine manually by a well trained operator and two assistants as shown in **Fig. 7**.

Before starting an experimental run, the required chopping concave was fitted into the chopping section. The clutch-gear box assembly was used to set the required speed and to transmit the power from the diesel engine to the threshing unit. The exact speed was then obtained by controlling the amount of fuel going into the engine. During each experimental run, the cylinder speed was measured by means of a tachometer. The time required for each run was measured by means of a stopwatch. Both the cylinder speed and the torque meter dial readings were recorded during the experiment.

The output materials under the threshing and chopping sections were collected and weighed separately and the grains were then separated from the straw and chaff using a small winnowing machine. The machine has a capacity of 150 kg grain per hour and was operated by 0.5 hp electric motor. For each section the separated grain and straw were weighed first and samples were then taken for laboratory analyses. The unthreshed heads were collected from the winnowing machine and rethreshed by small laboratory threshers. The machine was powered with 0.5 hp electric motor. The separated grain were weighed and the percent losses were calculated for each experimental run.



Fig. 7 Manual feeding of wheat bundles into the threshing machine by an operator and two assistants.

Field samples were transported to the Farm Machinery Laboratory of the Agricultural Engineering Department at the end of each working day. A portion of each sample was used to determine the moisture content; the remainder was used for the determination of visible and invisible seed damage, seed in tailings and length of straw.

The length of straw was measured by means of millimeter scale. The straw retained from the field sample was placed on a large wooden board in a form of a thin layer. Three working samples were then taken at random, each contained between 180 and 200 straws. The length of each straw was measured and recorded and the average length of straw in the sample was calculated.

Three working samples were taken at random from the remainder of each grain field sample for visible seed damage and seed in tailings determinations. The test was done by hand with the aid of frosted glass and forcepts. The samples were placed on the glass and damaged seeds and seed in tailings were removed and weighed separately; the percentage by weight for each category was then calculated.

The invisible seed damage was measured by running a germination test on that portion of the working samples which remained after removing both seed in tailings and damaged seeds. The germination test was carried out in a controlled growth chamber. Tests were run in triplicates and 100 seeds were used per replicate. The seedlings were counted on two stages. The first count was carried out after 4 days to remove the seedlings in order to give room for the remaining seeds to germinate. The second (final) count was carried out after 10 days from the start of the test and the material was discarded.

Results and Discussion

The experimental part of this study was confined to the determination of the performance criteria of the threshing machine. These criteria are the machine capacity, the power requirement, the total seed losses, the quality of the output seeds and length of straw.

Six levels of cylinder speeds (600, 700, 800, 900, 1 000 and 1 100 rpm) and four sizes of the chopping concave holes (22, 31, 38 and 48 mm diameter) were used in this study. The ambient temperature and crop moisture content were measured. However, their effects were not considered since there were no significant differences in the measured values.

Machine Capacity

For each experimental run, 30 kg of wheat bundles were fed manually into the machine. The time required for threshing the wheat material, at a given cylinder speed-hole diameter combination, was measured and the average feed rate of material into the machine was calculated. The capacity of the machine can be expressed as the feed rate or throughput material (wheat bundles) in t/h or as the output grain in t/h. It can also be expressed in ha/h if the yield per ha is known.

The machine feed rate as affected by cylinder speed and hole diameter is shown in **Fig. 8**. The feed rate of material into the machine increased by 0.83 t/h for all

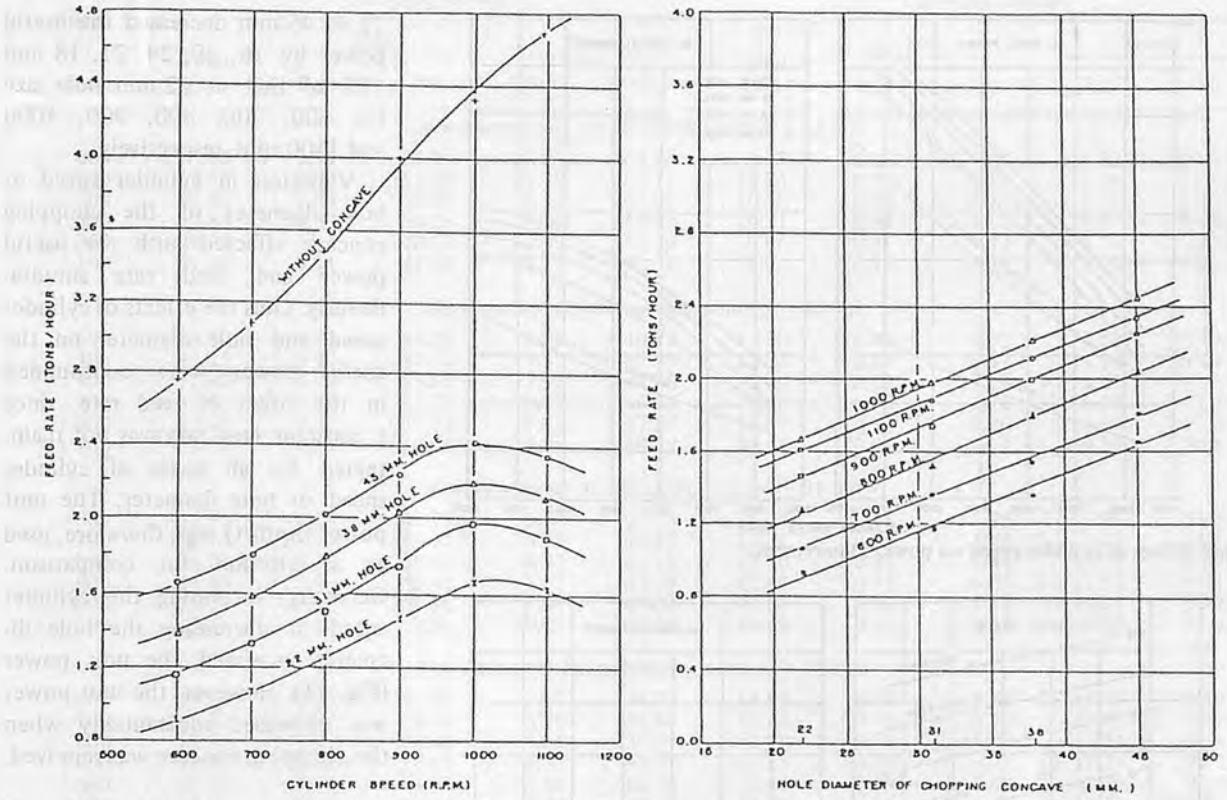


Fig. 8 Effect of cylinder speed and hole diameter of chopping concave on the feed rate of material.

hole diameters as the cylinder speed increased from 600 to 1 000 rpm. It was, however, decreased as the cylinder speed increased from 1 000 to 1 100 rpm. Increasing the cylinder speed from 600 to 1 000 rpm increased the feed rate by 90, 71, 61 and 50% of that at 600 rpm for 22, 31, 38 and 45 mm hole diameter of the chopping concave, respectively. When the concave of the chopping section was removed, a feed rate increase of 1.9 t/h (70%) was obtained when the cylinder speed was increased from 600 to 1 100 rpm.

For all cylinder speed, the feed rate of material into the machine increased linearly by 0.75 t/h as the hole diameter of the chopping concave was increased from 22 to 45 mm. In other words, increasing the hole diameter from 22 to 45 mm increased the feed rate by 80, 68, 62, 54, 48 and 47% of that at 22 mm diameter for cylinder speeds of 600, 700, 800, 900, 1 000 and 1 100 rpm, respectively.

Power Requirements

The torque on the shaft of the threshing-chopping cylinder was measured during the threshing process at various cylinder speed-hole diameter combinations. Then, the horsepower required for threshing operation (including chopping of straw) was calculated using the following formula:

$$hp = \frac{2 \times \pi \times N \times T}{60 \times 75}$$

where: N is the cylinder speed (rpm)

T is the torque on the cylinder shaft (kg·m)

The horsepower required to overcome the friction in the power transmission and torquemeter system and the useful power (power required for threshing process) were also calculated. The results are presented in **Figs. 9** and **10.**

The power required to overcome the friction in the moving parts increased with increasing rate as the cylinder speed increased from 600 to 1100 rpm. It was, however, not affected by the presence or absence of the chopping concave. The total power (the power measured during the threshing operation) was also increased as the cylinder speed increased from 600 to 1100 rpm; with increasing rate in the absence of the chopping concave and with decreasing rate in the presence of the chopping concave for all hole diameters.

The useful power (power required for threshing) was calculated by subtracting the friction power from the total power. It was noted that increasing cylinder speed from 600 to 1100 rpm increased the useful power by 95, 98, 134 and 155% of that at 600 rpm for 22, 31, 38 and 45 mm hole diameter of chopping concave, respectively. For all cylinder speeds, the useful horsepower decreased by 2 hp as the hole diameter of the chopping concave increased from 22 to 45 mm. In other words, increasing the hole diameter from

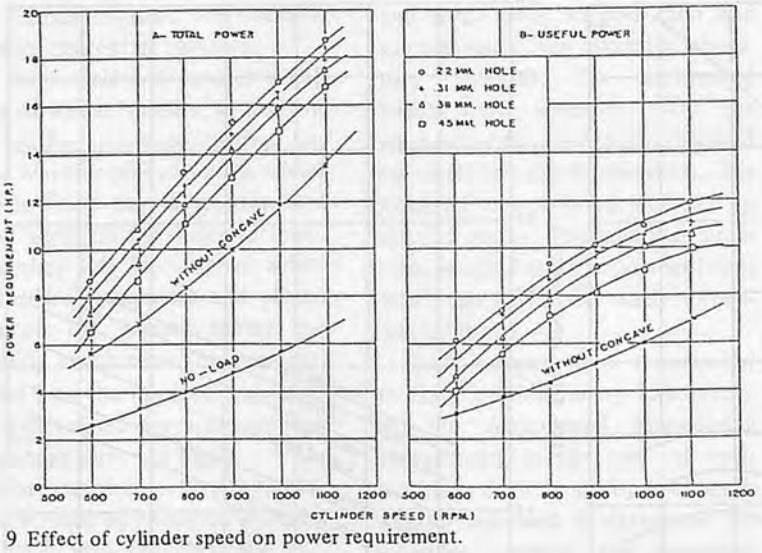


Fig. 9 Effect of cylinder speed on power requirement.

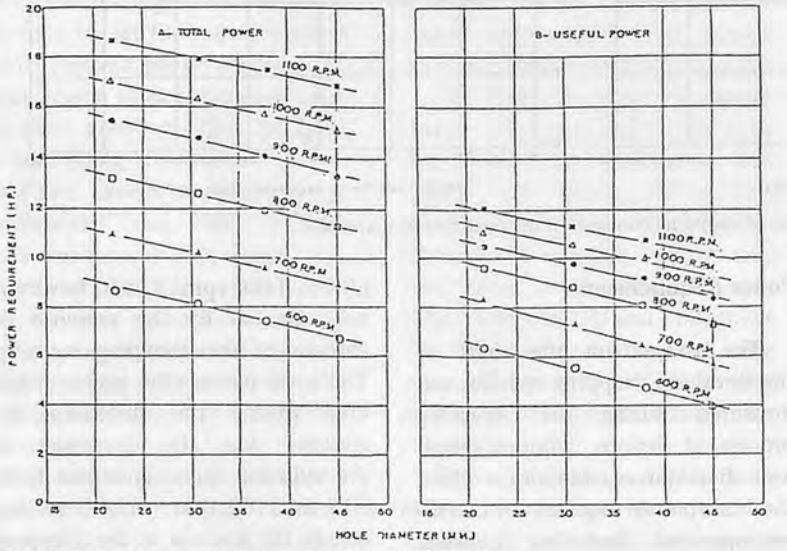


Fig. 10 Effect of hole diameter on power requirements.

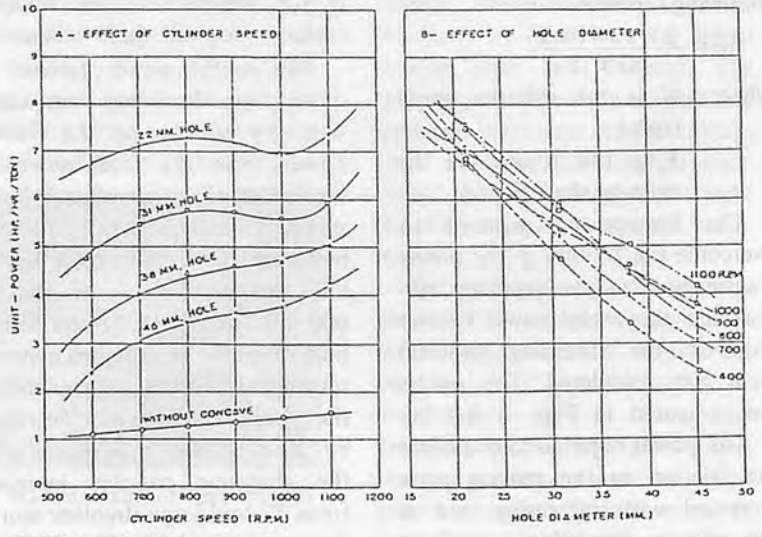


Fig. 11 The unit power.

22 to 45 mm decreased the useful power by 36, 29, 24, 21, 18 and 16% of that at 22 mm hole size for 600, 700, 800, 900, 1000 and 1100 rpm, respectively.

Variation in cylinder speed or hole diameter of the chopping concave affected both the useful power and feed rate simultaneously. Thus the effects of cylinder speed and hole diameter on the useful power were confounded in the effect of feed rate, since a constant feed rate was not maintained for all levels of cylinder speed or hole diameter. The unit power (hp/h/t) was, therefore, used as a criterion for comparison. Generally, increasing the cylinder speed or decreasing the hole diameter increased the unit power (Fig. 11). However, the unit power was decreased substantially when the chopping concave was removed.

Distribution and Analysis of Output Products

Threshing is accomplished partly by the impact of the fast moving beaters and partly by the rubbing and squeezing action between the beaters and the threshing concave. Thus, a high percentage of grain (up to 92%) with all chaff and a small quantity of fine straw penetrated the threshing concave. The beaters being inclined to the axis of rotation gave the straw an axial motion towards the chopping section. The straw was cut by the knives into pieces small enough to pass through the holes of the chopping concave. A small percentage of grain was found in the straw under the chopping section.

The distribution of the output mixture under both the threshing and chopping sections is shown in Table 3. For a given cylinder speed, increasing the hole diameter increased the amount of mixture that fell under the chopping section. On the other hand, for all

Table 3 Distribution of Output Mixture under the Threshing and Chopping Sections

Speed	Threshing section					Chopping section				
	Total	Seed		Straw		Total	Seed		Straw	
(rpm)	(kg)	(kg)	(%)	(kg)	(%)	(kg)	(kg)	(%)	(kg)	(%)
hole diameter of the chopping concave = 22 mm										
600	17.83	9.96	55.86	7.87	44.14	12.17	0.85	6.98	11.32	93.02
700	18.66	9.87	52.89	8.79	47.11	11.34	0.95	8.38	10.39	91.62
800	19.42	9.89	50.93	9.53	49.07	10.58	0.93	8.79	9.75	91.21
900	19.69	9.89	50.23	9.80	49.77	10.31	0.94	9.12	9.37	90.88
1 000	20.34	9.92	48.77	10.42	51.23	9.66	0.91	9.42	8.75	90.58
1 100	21.06	9.91	47.06	11.15	52.94	8.94	0.92	10.29	8.02	89.71
hole diameter of the chopping concave = 31 mm										
600	16.70	9.90	59.28	6.80	40.72	13.30	0.80	6.02	12.50	93.98
700	17.25	9.92	57.51	7.33	42.49	12.75	0.85	6.67	11.90	93.33
800	17.80	9.90	55.62	7.90	44.38	12.20	0.87	7.13	11.33	92.87
900	18.40	9.89	53.75	8.51	46.25	11.60	0.90	7.76	10.70	92.24
1 000	19.03	9.92	52.13	9.11	47.87	10.97	0.90	8.20	10.07	91.80
1 100	19.75	9.89	50.08	9.86	49.92	10.25	0.94	9.17	9.31	90.83
hole diameter of the chopping concave = 38 mm										
600	15.76	9.89	62.75	5.87	37.25	14.24	0.78	5.48	13.46	94.52
700	16.79	9.90	59.31	6.79	40.69	13.31	0.78	5.86	12.53	94.14
800	16.80	9.88	58.81	6.92	41.19	13.20	0.85	6.44	12.35	93.56
900	17.60	9.93	56.42	7.67	43.58	12.40	0.85	6.85	11.55	93.15
1 000	18.33	9.89	53.96	8.44	46.04	11.67	0.90	7.71	10.77	92.29
1 100	19.11	9.90	51.81	9.21	48.19	10.69	0.93	8.54	9.96	91.46
hole diameter of the chopping concave = 45 mm										
600	15.10	9.93	65.76	5.17	34.24	14.90	0.60	4.03	14.30	95.97
700	15.43	9.93	64.36	5.50	35.64	14.57	0.70	4.80	13.87	95.20
800	16.01	9.93	62.02	6.08	37.98	13.99	0.78	5.58	13.21	94.42
900	16.85	9.88	58.63	6.97	41.37	13.15	0.89	6.77	12.26	93.23
1 000	17.35	9.90	57.06	7.45	42.94	12.65	0.89	7.04	11.76	92.96
1 100	17.80	9.90	55.62	7.90	44.38	12.20	0.91	6.64	11.29	92.54
the chopping concave was removed										
600	9.30	6.82	73.33	2.48	26.67	20.70	3.16	15.27	17.54	84.73
700	9.62	6.86	71.31	2.76	28.69	20.38	3.19	15.65	17.19	84.35
800	9.98	6.84	69.23	3.04	30.77	20.12	3.27	16.65	16.85	83.75
900	10.15	6.86	67.59	3.29	32.41	19.85	3.32	16.72	16.53	83.28
1 000	10.43	6.88	65.96	3.55	34.04	19.57	3.38	17.27	16.19	82.73
1 100	10.70	6.90	64.49	3.80	35.51	19.13	3.43	17.77	15.87	82.23

hole diameters, increasing cylinder speed decreased the amount of mixture that fell under the chopping section and increased that which fell under the threshing section. Increasing cylinder speed increased the centrifugal and inertial forces and as a result more chaff and straw fell under the threshing section.

The distribution of grain and straw under the chopping and threshing sections is shown in Table 4. A large percentage of grain (92%) was separated and fell under the threshing section while the remainder was moved axially into the chopping section. The amount of seed recovered under the threshing section was not affected by cylinder speed nor the hole diameter. However, increasing the cylinder speed or decreasing the hole diameter reduced the amount of unthreshed heads and consequently increased the amount of seed recovered under the chopping section.

Both the cylinder speed and hole diameter affected the ratio of chaff and straw fallen under the chopping section. About 25 to 58% of the straw fell under the threshing section depending on the cylinder speed and hole diameter, the higher the speed and/or the larger the diameter the higher the percentage of straw.

Length of Straw

Wheat straw is used as a roughage in animal feeding. It is also used for making adobe and red bricks, the most commonly used building materials in Egypt. Therefore, the second important purpose of the threshing process (after recovering the seed free from plant residue) is cutting the straw to an acceptable length that is suitable for either animal feed or use in the brick industry.

Inspection of the straw under the threshing and chopping section showed that the non-grain material which fell under the threshing section consisted of glumes, leaf fragments, awns and short straw fragments of non-circular cross section; while that which fell under the chopping section consisted of straw fragments of circular and non-circular cross sections.

The effect of cylinder speed and hole diameter of the chopping concave on the length of straw was profound. Increasing the cy-

Table 4 Distribution of Output Grain and Straw under Threshing and Chopping Sections

Speed (rpm)	Grain					Straw				
	Total (kg)	Threshing section (kg)	Threshing section (%)	Chopping section (kg)	Chopping section (%)	Total (kg)	Threshing section (kg)	Threshing section (%)	Chopping section (kg)	Chopping section (%)
hole diameter of the chopping concave = 22 mm										
600	10.81	9.90	92.19	0.85	7.81	19.19	7.87	41.01	11.08	58.99
700	10.82	9.87	91.22	0.95	8.78	19.18	8.79	45.83	10.39	54.17
800	10.82	9.89	91.40	0.93	8.60	19.18	0.53	49.69	9.75	50.31
900	10.83	9.89	91.32	0.94	8.68	19.17	9.80	51.12	9.37	48.88
1 000	10.83	9.92	91.60	0.91	8.40	19.17	10.42	54.36	8.75	45.64
1 100	10.83	9.91	91.50	0.92	8.50	19.17	11.15	58.16	8.02	41.84
hole diameter of the chopping concave = 31 mm										
600	10.70	9.90	92.52	0.80	7.48	19.30	6.80	35.23	12.50	64.77
700	10.77	9.92	92.11	0.85	7.89	19.23	7.33	38.12	11.90	61.88
800	10.77	9.90	91.92	0.87	8.08	19.23	7.90	41.08	11.33	58.92
900	10.79	9.89	91.66	0.90	8.34	19.21	8.51	44.30	10.70	55.70
1 000	10.82	9.92	91.68	0.90	8.32	19.18	9.11	47.50	10.07	52.50
1 100	10.83	9.89	91.32	0.94	8.68	19.17	9.86	51.43	9.31	48.57
hole diameter of the chopping concave = 38 mm										
600	10.67	9.89	92.69	0.78	7.31	19.33	5.87	30.37	13.46	69.63
700	10.68	9.90	92.70	0.78	7.30	19.32	6.79	35.14	12.53	64.86
800	10.73	9.88	92.08	0.85	7.92	19.27	6.92	35.91	12.35	64.09
900	10.78	9.93	92.12	0.85	7.88	19.22	7.67	39.91	11.55	60.09
1 000	10.79	9.89	91.66	0.90	8.34	19.21	8.44	43.94	10.77	56.06
1 100	10.83	9.90	91.41	0.93	8.59	19.17	9.21	48.05	9.96	51.95
hole diameter of the chopping concave = 45 mm										
600	10.53	9.93	94.30	0.60	5.70	19.17	5.17	25.40	14.30	74.60
700	10.63	9.93	93.41	0.70	6.59	19.37	5.50	28.39	13.87	71.61
800	19.71	9.93	92.72	0.78	7.28	19.29	6.08	31.52	13.21	68.48
900	10.77	9.88	91.74	0.89	8.26	19.23	6.97	36.25	12.26	63.75
1 000	10.79	9.90	91.75	0.89	8.25	19.21	7.45	38.78	11.76	61.22
1 100	10.81	9.90	91.58	0.91	8.42	19.29	7.90	41.47	11.29	58.53
the chopping concave was removed										
600	9.98	6.82	68.34	3.16	31.66	20.02	2.48	12.39	17.54	87.61
700	10.05	6.86	68.27	3.19	31.73	19.95	2.76	12.83	17.19	86.17
800	10.11	6.84	67.66	3.27	32.34	19.89	3.04	12.28	16.85	84.72
900	10.18	6.86	67.39	3.32	32.61	19.82	3.29	12.60	16.51	83.40
1 000	10.26	6.88	67.06	3.38	32.94	19.74	3.55	12.98	16.19	82.02
1 100	10.33	6.90	66.80	3.43	33.20	19.67	3.80	12.32	15.87	80.68

linder speed decreased the length of both chaff (threshing section) and straw (chopping section). Although the hole diameter did not affect the length of chaff, decreasing the hole diameter decreased the length of straw fallen under the chopping section.

Seed Losses

Threshing of wheat by this type of threshing machine resulted in two types of losses; the unthreshed heads and the seed in tailings. The results obtained in this study are presented in Figs.12 and 13.

Increasing the cylinder speed or decreasing the hole diameter increased the amount of unthreshed seeds. For most hole diameter threshing losses would be nil at cylinder speed of 1100 rpm.

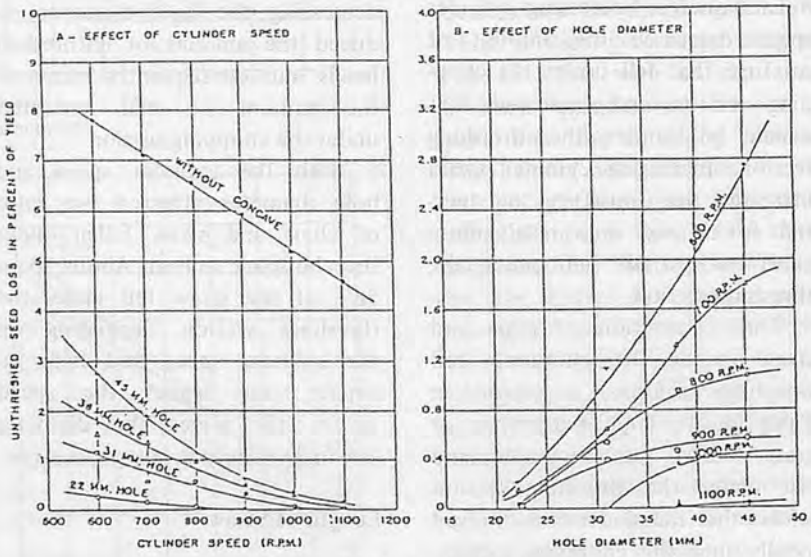


Fig. 12 Unthreshed seeds.

Seed in tailings occurs only with this type of machine. This is undesirable in seeds that will be milled and used in human feeding. Increasing the cylinder speed or decreasing the hole diameter decreased the amount of

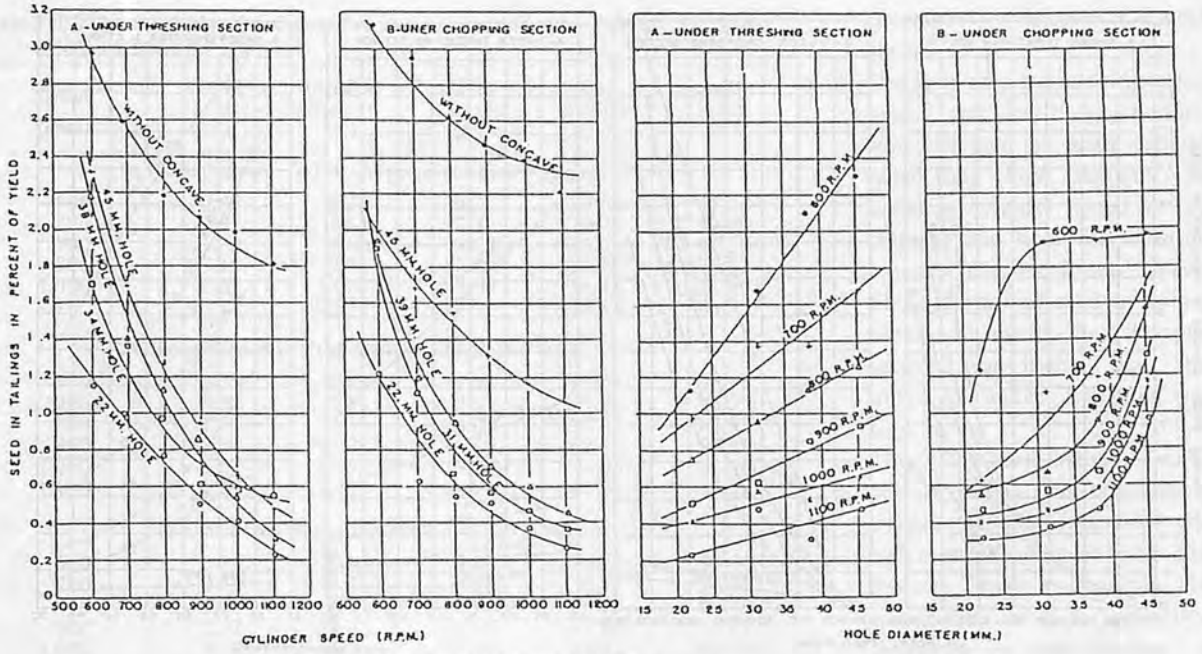


Fig. 13 Seeds in Tailings.

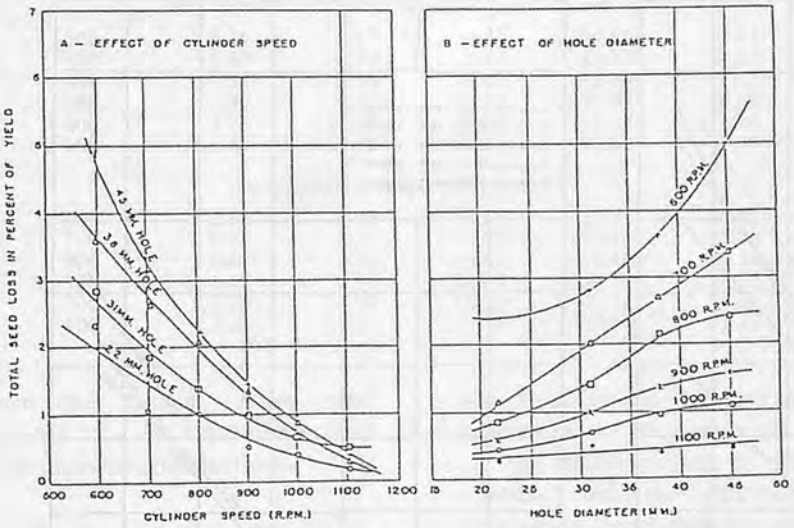


Fig. 14 Total seed losses.

seed in tailings under both the threshing and chopping sections.

The total threshing losses as calculated in this study is the summation of the unthreshed losses and seed in tailings. These are shown in **Fig. 14**. Less than 0.5% of the seed losses occurred at 1000 rpm for all hole diameters.

Seed Damage

Damage occurs primarily because of the impact of the blows received by the seeds during the threshing process. The damage may be visible (external) or invisible (internal). The latter type was determined by germination test. Seed damage does not represent a direct loss of yield except for seeds broken into pieces that are too small to be recovered. Seed damage may however reduce the quality and value of products depending upon the intended use of grain. Internal seed damage, as it affects germination is an important consideration when grains are to be used for planting purpose. The term seed index is used to indicate the percent pure live seeds and is used as an indicator of the expected germination rate.

The visible and invisible seed damage results are presented in **Figs. 15** and **16**. The seed quality and seed index are also shown in **Table 5**. Increasing cylinder speed increased the visible seed damage under both the threshing and chopping sections. Under the threshing section, the visible seed damage increased slightly as the cylinder speed increased, it was less than 2% up to cylinder speed of 900 rpm. The visible seed damage was increased rapidly (from 3 to 10%) when the cylinder speed increased from 900 to 1100 rpm. The percent seed damage under the chopping section was higher than that under threshing section for all cylinder speed-hole diameter combinations. This may be due to the existing sharp knives in the chopping section.

The effect of hole diameter on the visible seed damage was more pronounced at higher cylinder speed than the lower ones. In general, increasing the hole di-

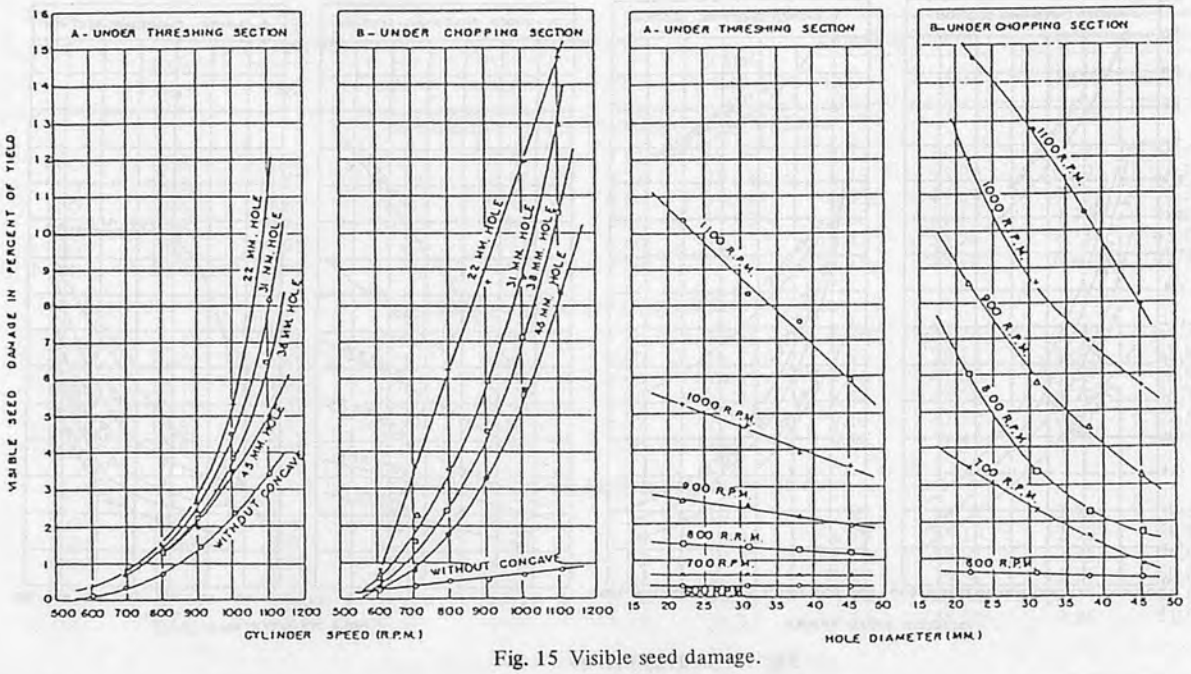


Fig. 15 Visible seed damage.

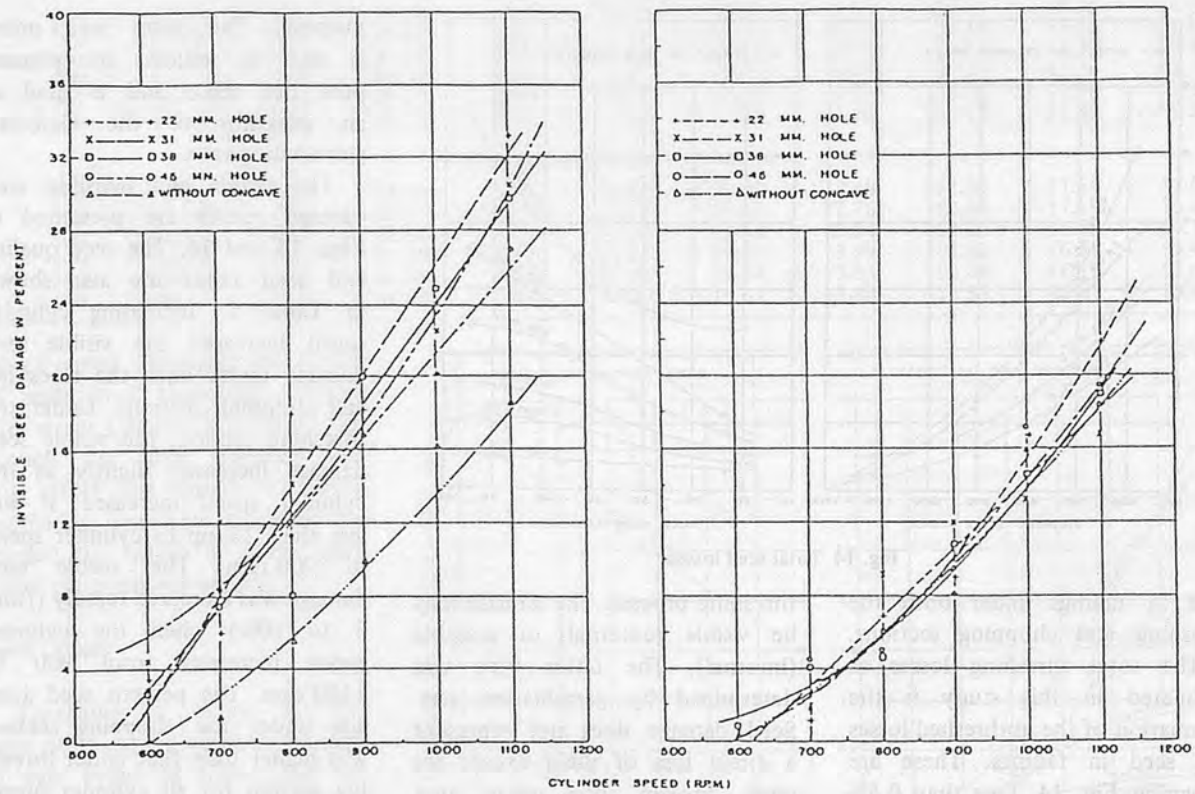


Fig. 16 Invisible seed damage.

ameter decreased the seed damage. It was also noticed that the hole diameter had more effect on the visible seed damage in the chopping section than in the threshing section.

The percent invisible seed damage as was determined by germination test was affected by cylinder speed. Increasing cylinder speed increased the invisible seed damage. The hole diameter did not have any significant effect on the invisible seed damage. However, more invisible seed damge was obtained under the chopping section. It was also noted that the percent invisible seed damage was higher

Table 5 Effect of Cylinder Speed and Hole Diameter of Chopping Concave on Seed Quality and Seed Index

Speed (rpm)	Visible damage (%)	Invisible damage (%)	Total damage (%)	Seed quality (%)	Seed index (%)
hole diameter of the chopping concave = 22 mm					
600	0.39	0.38	0.77	99.61	99.23
700	0.97	1.54	2.51	99.03	97.49
800	1.97	7.80	9.77	98.03	90.23
900	3.15	9.74	12.89	96.85	87.11
1 000	5.82	17.27	23.09	94.18	76.91
1 100	11.55	22.70	34.25	88.45	65.75
hole diameter of the chopping concave = 31 mm					
600	0.39	0.70	1.09	99.61	98.91
700	0.80	2.81	3.61	99.20	96.39
800	1.56	9.52	11.08	98.44	88.92
900	2.84	12.21	15.05	97.16	84.95
1 000	5.02	13.98	19.00	94.98	81.00
1 100	8.69	17.99	26.68	91.31	73.32
hole diameter of the chopping concave = 38 mm					
600	0.36	1.04	1.40	99.64	98.50
700	0.73	4.25	4.98	98.27	95.02
800	1.37	4.87	6.24	98.63	93.76
900	2.37	11.66	14.03	97.63	85.97
1 000	4.17	15.48	19.65	95.83	80.35
1 100	7.79	19.87	27.66	92.21	72.34
hole diameter of the chopping concave = 45 mm					
600	0.36	0.17	0.53	99.64	99.47
700	0.67	4.70	5.37	99.33	94.63
800	1.31	5.56	6.87	98.69	93.13
900	2.09	8.82	10.91	97.91	89.09
1 000	3.75	17.57	21.32	96.25	78.68
1 100	6.40	19.93	26.33	93.60	73.67
the chopping concave was removed					
600	0.18	0.00	0.18	99.82	99.82
700	0.42	1.59	2.01	99.58	97.99
800	0.60	5.82	6.42	99.40	93.58
900	1.43	9.94	11.37	98.57	88.63
1 000	2.28	16.08	18.36	97.72	81.64
1 100	3.22	18.25	21.47	96.78	78.53

than the percent visible seed damage for all cylinder speed-hole diameter combinations.

Conclusions

1. The feed rate of material was affected by both the cylinder speed and the hole diameter of the chopping concave. It was increased when the cylinder speed was further increased from 600 to 1000 rpm and then decreased as the cylinder speed was further increased from 900 to 1100 rpm. For all cylinder speeds, the feed rate increased linearly as the hole diameter increased from 22 to 45 mm.
2. The feed rate of the machine depended to a great extent on the training level of the operator and the efficiency of labourer responsible for conveying the crop from the heap to the feed table. Manual feeding caused peak loads on the machine amounting to 140% of the average load. The maximum fluctuation in load during the threshing process was about 50% of the average load.
3. The useful power required for threshing the wheat crop was mainly affected by the cylinder speed; the effect of hole diameter was not profound. A 25-hp engine seemed to be sufficient for driving the machine. This power would include allowance for friction and peak loads.
4. The total seed losses (unthreshed seeds and seed in tailings) were affected by both cylinder speed and hole diameter. Increasing cylinder speed or decreasing the hole diameter decreased the tatal seed losses. The quantity of seed in tailings obtained under the chopping section was higher than that obtained under threshing section.
5. The total seed damage (visible and invisible) was affected by cylinder speed, increasing cylinder speed increased the seed damage rapidly. The hole diameter did not have appreciable influence in seed damage, although more damage was noticed in seeds collected under chopping section than that collected under the threshing section.
6. Increasing cylinder speed or decreasing the hole diameter reduced the length of straw under the chopping section. They did not affect the length of chaff under the threshing section.
7. Most threshed grain (92%) fell under the threshing section, the remainder fell under the chopping section. The ratio was not affected by neither cylinder speed nor hole diameter.
8. The optimum operating condition of threshing wheat can be obtained at cylinder speed of 1000 rpm using a chopping concave with 45 mm hole diamer. The performance criteria of the machine using a chopping concave with holes of 45 mm diameter is shown in **Fig. 17**.

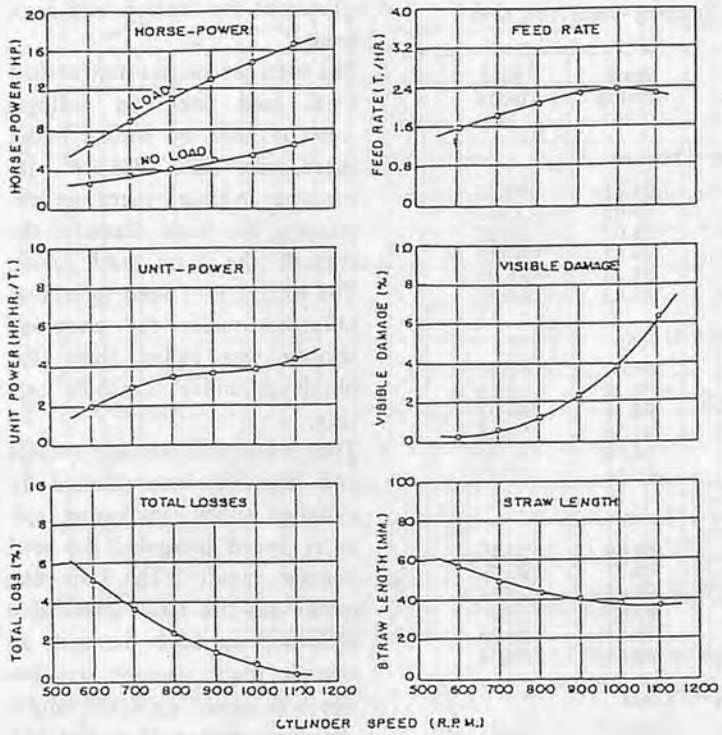


Fig. 17 Performance criteria of the threshing machine.

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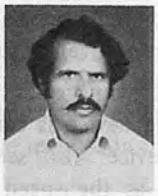
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Modification and Testing of Bullock-Drawn, Single-Row Corn Planter



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Abstract

Uniform spacing between plants is an essential requirement of cross cultivation. Conventional bullock-drawn corn planter does not fulfill this requirement. Hence the planter was modified by mounting a metering device (wooden rotor) in between the bowl and tube to give uniform spacing between seeds. The modified implement was then tested and found useful as compared with a conventional one.

Introduction

Maize is grown as Kharif crop both for grain and fodder in Pakistan. It has great importance in the world from acreage and production points of view. For fodder, corn is broadcast and for grain purpose it is sown by drilling method.

Tremendous research work has been done on tractor-drawn planters but little research has been devoted towards the design of simple, low-cost, durable and versatile bullock-drawn, precision planters.

The existing traditional bullock-drawn planter (Fig. 1) consists of a tube and bowl. It lacks metering device, therefore, it cannot place the seeds at uniform spacing. Lack of this feature does not permit cross cultivation, hence hand-weeding and herbicides increase the cost of production.

To improve its performance, the implement was modified. A wooden rotor was mounted in between the bowl and the tube (Fig. 2). A groove approximately equal to the size of maize grain was made on the periphery of the rotor. An iron handle was fixed on the right hand side of the axle. The modified planter was then tested and compared with conventional one to evaluate the improvement in the performance of the machine.

Testing Procedure

From the review of past research (1,2,3,4,) it is observed that the ultimate criterion for evaluating the performance of the planting machine is the stand obtained in the field which is influenced by seed viability and environmental factors. The effects of different types of furrow openers can only be de-

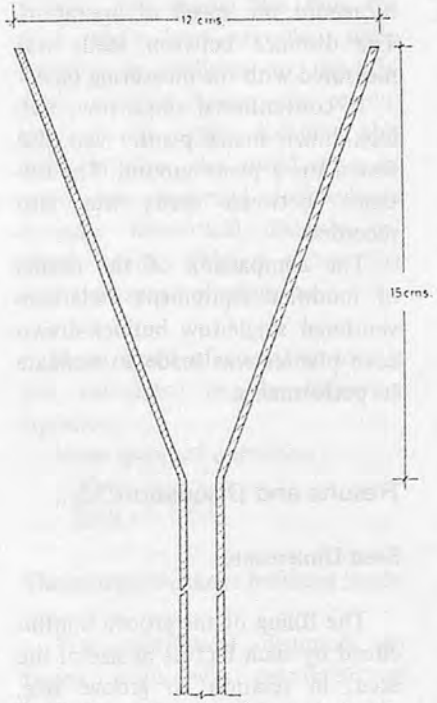


Fig. 1 Conventional single-row, bullock-drawn corn planter.

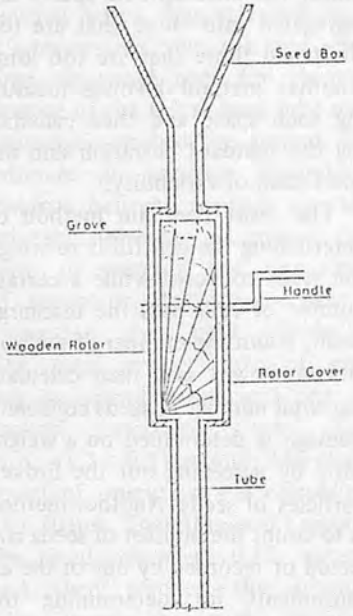


Fig. 2 Sectional view of single-row, bullock-drawn and hand-operated precision corn planter.

termined by field emergence trials but the performance of seed metering device can be checked more readily and more reliably in the laboratory than in the field. The regularity of seed spacing can be observed rather simply by mounting the hopper and metering device on a suitable stand and passing a grease-coated belt beneath the seed tube at a rate representing the ground speed of the planter. The resulting seed pattern is representative of the performance of the metering device with its seed tube but does not show the effect of bouncing in the furrow. However, for this purpose photosensitive devices and electronic units have also been used to record the paths or frequencies of falling seeds. The performance of metering device alone is often expressed as the percentages of skips, singles, doubles and multiples. Various methods have been employed to evaluate or compare seed distribution pattern. Some investigators have assumed an acceptable range or tolerance for the seed spacing and then determine the percentage of spaces within this range. Sometimes, the unacceptable spaces are segregated into those that are too short and those that are too long. Another method involves measuring each space and then calculating the standard deviation and the coefficient of variability.

The most common method of determining the cell fill is to weigh the seeds collected while a certain number of cells pass the discharge point, count the number of seeds in known weight and then calculate the total number of seeds collected. Damage is determined on a weight basis by screening out the broken particles of seeds. Another method is to count the number of seeds collected or recorded by one of the arrangements for determining the regularity of spacing. The counting method gives a direct indication of the number of seeds discharged by each individual cell and the probability of cells selecting zero, one, two or any other number of seeds whereas the weighing method merely indicates the overall average.

For testing the modified single-row, bullock-drawn corn planter, a 30-m strip on the plane ground was selected, and was coated with thick film of sand to minimize the seed slip on the test ground. The tube of the planter was also made very narrow to reduce the bouncing of the seeds during travel through the tube. The single cell rotor made of wood was used; above it a seed box of 0.5-kg capacity was mounted. The rotor has the cell somewhat larger than the uniform seeds, hence multiple cell filling was minimized. Since a single seed could easily accommodate in the cell and other seeds could slip easily while revolving the rotor, hence the seed breakage was eliminated.

The seed box filled with seeds, the seed metering device was rotated with hand for a test distance of 30 m was covered with the speed of 1.2 m/s. A stopwatch was used to record the speed of operation. The distance between seeds was measured with the measuring tape.

A conventional single-row, bullock-drawn maize planter was also tested on a plane ground. The distance between seeds was also recorded.

The comparison of the results of modified equipment with conventional single-row bullock-drawn corn planter was made to evaluate its performance.

Results and Discussion

Seed Dimensions

The filling of the groove is influenced by such factors as size of the seed, in relation to groove size, shape of the seeds, the shape of the groove, the exposure time of the groove to seed in the hopper and the linear speed of the groove.

To evaluate the performance of the equipment designed, uniform seeds of J-1 corn variety were selected to avoid the double filling, and clogging of the seeds which is uneconomical from a mechanized agriculture point of view.

Seed Damage

Most seed damage in vertical rotor metering device is caused by the cut-off device. Also, seed damage increases as the speed of the rotor increases. Damage is also great if the grooves are too large. However, in the test equipment, there was no cut-off device so there were less chances of seed damage. Rotor speed was also under control. There are two methods for determining the seed damage: one is on weight basis, in this method, the broken particles of the seeds are screened out and then weighed, thus the percentage of damage can be calculated. Another method is to count the number of broken seeds and then calculate the damage on percentage basis. To evaluate the performance of the equipment, a second method was used to calculate the damage of seeds though the first method was also easy and could be used.

Twenty-five seeds were placed in the hopper of the planter and the rotor was rotated. The damaged seeds were recorded each time. The test was replicated four times. Thus from the data obtained, the seed damage was calculated. **Table 1** indicates the damaged and undamaged seeds on a percentage basis.

Table 1 Damaged and Undamaged Seeds

Replications	Seeds dropped (No.)	Seeds damaged (%)	Seeds undamaged (%)
1	25	4	96
2	25	0	100
3	25	4	96
4	25	0	100

Speed of Rotor

From past research reviewed (1) it was found that the effect of rotor speed appears to be much greater for rough-surfaced seeds than for large, smooth seeds. Doubles are more likely to occur at low rotor speed with small seeds than with large seeds. It was, therefore, decided that the speed of the rotor in revolutions per second be evaluated so that the time taken in seconds by the groove during one complete revolution of the rotor.

Drop Time of Seed from Rotor to Ground

Precise metering is of little value unless the seeds are controlled so that each requires the same time from the meter to the furrow, unless bouncing and rolling in the furrow are minimized. These factors are especially critical for close spacing in row and for high forward speeds. From review of literature (2) it is found that when drilling at 3 miles per hour with seeds spaced 2 inches apart in the row, a seed that is dealyed 1/25 s will be overtaken by the next seed.

The aim of this test was to determine the time taken in seconds by seed drop from totor to the ground and then to correlate with the forward speed of the equipment. During this test no overlapping of the seeds was observed. **Table 3** shows the drop time of seeds in seconds from rotor to ground.

Variation in drop time could have occured due to the following reasons:

1. The drop tube was long, rough, and wide.
2. Seed was not discharged directly from the metering unit within a few inches of the furrow bottom.

Speed of Operation

Table 2 Time Taken for one Revolution of Wooden Rotor

Replication	Time (s)					
	1	2	3	4	5	Mean
1	1.0	1.5	1.0	1.3	1.4	1.2
2	1.3	1.5	1.2	1.5	1.4	1.3
3	1.5	1.4	1.0	1.3	1.2	1.2
4	1.2	1.5	1.4	1.3	1.5	1.3
Mean	1.2	1.4	1.1	1.3	1.3	1.2

Table 3 Drop Time of Seeds from Rotor to Ground

Replication	Seed drop time (s)								
	1	2	3	4	5	6	7	8	Mean
1	1.0	2	1	2.0	1.5	1.0	1.1	1.1	1.5
2	1.0	1	1	1.2	2.0	1.5	1.3	1.0	1.3
3	1.3	1	1	2.0	1.2	2.0	1.2	1.2	1.4
4	1.2	1	2	1.4	1.0	1.1	2.0	1.0	1.3
5	1.0	2	1	1.5	1.0	1.2	1.7	1.3	1.3
6	1.1	1	2	2.0	1.0	1.0	1.5	1.2	1.3
7	1.0	1	1	1.5	1.1	1.5	1.2	1.0	1.2
Mean	1.1	1.3	1.3	1.7	1.4	1.5	1.3	1.1	1.3

Table 4 Time Taken in Seconds for 30 m at Normal Speed

Replications	Time (s)											
	1	2	3	4	5	6	7	8	9	10	11	Mean
Time taken at normal speed	25	30	25	28	26	25	25	24	25	26	25	25.8

Since the rotor was not fitted close enough to the ground, the seed took some time to reach the ground, and during this time the seed might have travelled some distance in addition to the distance covered during one revolution of the rotor. Keeping this point in view, the speed of operation was recorded to evaluate accurate theoretical distance between seeds. **Table 4** shows the results of speed of operation.

Mean speed of operation in m/s was calculated by the following equation:

Mean speed of operation

$$= \frac{30\text{m}}{25.8\text{ s}} = 1.2$$

Theoretical Distance between Seeds

The theoretical distance between seeds was calculated as follows:

Circumference

$$= \pi d = 15.2\text{ cm} \times \frac{22}{7} = 0.48\text{ m}$$

The distance between seeds could be 0.48 m if the rotor was fitted close enough to the ground, but since the rotor was fitted in a housing which was attached to a 0.9 meter-long tube, the seed took time to travel over the circumference of the 0.9 m long tube and ultimately reached the ground. To estimate an accurate theoretical distance between seeds it was absolutely necessary to record the time in seconds per revolution of the rotor. For this purpose a stopwatch was used **(Table 2)**. The total average time of seed fall in seconds from seed box to ground recorded was 0.1 (1.3 – 1.2 = 0.1) second. The mean speed of operation was calculated at 1.20 m/s. Therefore in 0.1 second the seed travelled 0.12 meters and then reached the ground. Thus total theoretical distance between seeds was 0.48 m + 0.12 m = 0.60 m.

Experimental Spacing between Seeds

The aim of this test was to determine the spacing between seeds during normal speed of operation. A test was performed on the ground and the distance between seeds in meters was measured with tape. Table 5 shows the distance between seeds. It is clear from the table that the coefficient of variance is within acceptable range. Table 6 shows the theoretical and experimental distance between seeds.

Table 5 Seed Spacing on Plane Ground

Replications	Seed spacing (m)									
	1	2	3	4	5	6	7	8	9	10
1	0.38	0.50	0.65	0.57	0.53	0.54	0.60	0.64	0.33	0.57
2	0.53	0.60	0.54	0.65	0.38	0.50	0.81	0.65	0.57	0.34
3	0.40	0.38	0.34	0.53	0.65	0.50	0.78	0.58	0.55	0.50
Mean	0.4	0.5	0.5	0.6	0.5	0.5	0.7	0.8	0.5	0.05
Standard deviation	0.076	0.09	0.099	0.09	0.077	0.023	0.097	0.039	0.11	0.1
Coefficient of variance	19	18	20	15	15	5	14	7	22	20

Table 6 Comparison between Theoritical and Experimental Distance between Seed to Seed

Replication	Distance between seeds (m)									
	1	2	3	4	5	6	7	8	9	10
Theoretical distance between seeds	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Experimental mean distance between seeds	0.4	0.5	0.5	0.6	0.5	0.5	0.7	0.6	0.5	0.5
Mean	0.5	0.55	0.55	0.6	0.55	0.55	0.65	0.6	0.55	0.555
Standard deviation	0.1	0.05	0.05	0.0	0.05	0.05	0.05	0.05	0.05	0.05
Coefficient of variance	20	10	10	0.0	10	10	10	0.0	10	10

Test of Conventional Corn Planter

The aim of this test was to compare the results of conventional single-row, bullock-drawn equipment with the modified implement and to identify the equipment that gives the best results in terms of uniform seed spacing. For this purpose, a 30 m long strip was selected and the seed was poured into the bowl by hand with great care to maintain the distance between seeds. The spacings between seeds were measured with a steel rule. The results are shown in Table 7.

The coefficient of variance is not within acceptable range. Hence, it is obvious that the performance of conventional single-row, bullock-drawn maize planter is poor as compared to the modified planter.

Table 7 Distance between Seeds Sown by Conventional Planter

Replication	Distance between seed to seed (m)									
	1	2	3	4	5	6	7	8	9	10
1	0.47	0.57	0.37	0.50	0.46	0.50	0.46	1.20	0.76	0.72
2	0.44	0.46	0.84	0.46	0.62	0.62	0.43	0.73	0.45	0.53
3	0.32	0.44	0.30	0.87	0.42	0.28	0.46	0.49	0.38	0.40
Mean	0.37	0.55	0.55	0.57	0.49	0.43	0.42	0.71	0.54	0.59
Standard deviation	0.09	0.12	0.23	0.17	0.08	0.13	0.05	0.31	0.15	0.16
Coefficient of variance	24	22	42	30	16	30	12	43	27	28

Conclusions

The modified single row bullock-drawn maize planter gives better results as compared with those of conventional single-row, bullock-drawn maize planter. However, variations in drop time were observed because the drop tube was long and rough. The variations in drop time could have resulted in the non-uniformity in the spaces between seeds. The modified planter could be used successfully for sowing corn in hills by changing the rotor made for the purpose. Any required distance between seeds could be obtained by replacing the rotors. The modified planter could also be used for planting soybeans, peas, sunflower, etc. by changing the seed plate (rotor).

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Weed Control through Inter-Row Cultivation in Upland Rice

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Abstract

Two inter-row cultivations with a hand-hoe or a high wheel cultivator plus hand-weeding in the rows 14 and 28 days after rice emergence (DAE) resulted in yields which were equivalent to those from the weed-free check, which received four weedings. There was no significant difference in grain yield between the plots where the rolling weeder was used twice and those which were hand-weeded twice, but both yielded significantly lower than the weed-free check.

The time required for weeding was 1% with the rolling weeder, 9% with high wheel cultivator, and 10% with the hand-hoe compared with hand-weeding. The net returns to weeding with those treatments, which were low because the crop suffered from drought, were $67.00, $61.70, and $88.20/ha, respectively. Because of the large labor cost involved, the use of hand-weeding in the rows in combination with inter-row cultivation and herbicide resulted in a lower net return to weeding.

Hand-weeding in rows after inter-row cultivation resulted in an average yield increase of 0.5 t/ha. Inter-row cultivation plus hand-weeding in the rows may be able to substitute for the highly labor-intensive hand-weeding presently used by many farmers.

Introduction

Weeds are one of the major problems of production technology for upland rice (*Oryza sativa* L.). Hand-weeding is the most common method of weed control in rice, but it requires a very high labor input. The labor requirement for weeding can be very variable and depends on such factors as weed intensity, time of weeding, conditions at the time of weeding, and efficiency of the weeders. De Datta and Ross (1975) reported that a single hand-weeding in upland rice required about 300 man-h/ha and, often, several such weedings were needed to keep the crop weed-free. In Brazil, about 1,200 man-h/ha were required to do a single hand weeding of upland rice planted in rows spaced 40-50 cm apart (De Datta et al, 1974). Singh et al (1981) reported that two hand weedings of upland rice required 1 964 man-h/ha.

Hand-hoes can be used as an aid for weed control in upland rice. They reduce the time required for weeding and the corresponding costs involved to less than half that required for hand-weeding (Curfs, 1976; Singh et al, 1976). Inter-row cultivation has generally not been used very successfully in upland rice. In Fiji, inter-row cultivation was used for weed control in upland rice planted at wide row spacings (Patel and Rhodes, 1969), but in the Malagasy Republic, attempts to use animal-drawn equipment were unsuccessful (Le Moigne, 1971). In West Africa, both in the Ivory Coast (Renaut, 1972) and in Nigeria (IITA, 1973), attempts to control weeds by inter-row cultivation have failed.

Uprooting or severe damage to rice plants will occur if cultivation is carried out too close to the rice row. Weeds within and close to the row are not controlled and are the most deleterious because they are highly competitive. Appreciable yield losses may result (Moody, 1977). Renaut (1972) stated that any weed control achieved by inter-row cultivation would be virtually ineffective. However, Moody (1973) noted that if weeds within the row can be controlled by chemical means, then inter-row cultivation has distinct possibilities.

In upland rice, timely cultivation is sometimes not possible because of adverse soil or weather conditions (Moody, 1977). Inter-row cultivation works extremely well under ideal climatic and soil conditions, but heavy rains soon after planting prevent the use of mechanical weed control techniques in heavy, sticky clay soils (Moody and Mukhopadhyay, 1982). Also, if it rains soon after inter-row cultivation, the weeds may quickly re-establish themselves with little or

no apparent injury (Moody, 1977).

Herbicides can reduce the labor requirement tremendously but inconsistency in their performance; their cost relative to labor; farmers' lack of knowledge about the rate, time and method of application; and the unavailability of herbicides and sprayers are some of the major factors that restrict their use by most small-scale farmers (Singh et al, 1981).

There is need to develop a suitable weed control method for upland rice that will maximize the efficiency of the limited resources of small-scale farmers. A combination of two or more methods of weed control at low input levels so as to reduce the weed competition to a minimum seems the most appropriate proposition.

Lusanandana (1978) recommended that research for weed control should focus on tillage practices such as inter-row cultivation and other cultural practices. Such research should be directed toward modification of the native implements already in use before undertaking the design of new implements.

This study was conducted to evaluate the efficiency of different types of inter-row cultivation equipment (Figs. 1-3) alone and in combination with other weed control methods in controlling weeds and reducing weeding time in upland rice.



Fig. 1 Hand hoe.

Materials and Methods

This experiment was conducted in a dryland field at the International Rice Research Institute (IRRI) experimental farm during the 1980 wet season. Sixteen weeding treatments were replicated three times in a randomized complete block design. Rice (cv. IR50) was sown using an inclined plate seeder on August 19, 1980. The row spacing was 30 cm and seeding rate was 100 kg/ha. Sixty kilograms of N, 40 kg P_2O_5, and 40 kg K_2O/ha were applied during the last rotary tilling prior to seeding and 20 kg N/ha was applied at 30 DAE and at panicle initiation.

In all plots except the unweeded check, the weed-free check, and the herbicide-treated plot, weeding was done twice: 14 and 28 DAE. Two additional hand-weedings at 42 and 56 DAE were required in the weed-free check. In the herbicide-treated plot, pendimethalin [N-(1-ethylpropyl)-3, 4-dimethyl-2, 6-dinitrobenzenamine] was applied at 1.5 kg a.i./ha just after seeding the crop. Weed samples were taken at 14, 28, 42, and 70 DAE from two 0.5 x 0.5 m quadrats in each plot and pooled. The dry weight was recorded after the samples were classified into broadleaf weeds, grasses, and sedges. The crop was harvested from a 9-m^2 sampling area per plot on November 26, 1980, and grain yields were adjusted to 14% moisture.

Results and Discussion

Weed species growing in association with the crop were *Portulaca oleracea* L., *Amaranthus spinosus* L., *Commelina benghalensis* L., *Mimosa pudica* L., *Euphorbia hirta* L., *Phyllanthus niruri* L., *Cleome viscosa* L., *Echinochloa colona* (L.), Link, *Eleusine indica* (L.) Gaertn., *Rottboellia exaltata* L.f., *Digitaria* sp., *Cynodon dactylon* (L.) Pers., *Leptochloa chinensis* (L.) Nees, and *Cyperus rotundus* L. On the basis of relative dry weight, the sedges dominated 14 DAE, but the grasses increased in importance after the first sampling and were the most important group by 42 DAE. In contrast, the sedges tended to decrease in importance with time. The relative dry weight of broadleaf weeds, which were a minor component of the weed flora, increased up to 42



Fig. 2 High wheel cultivator.

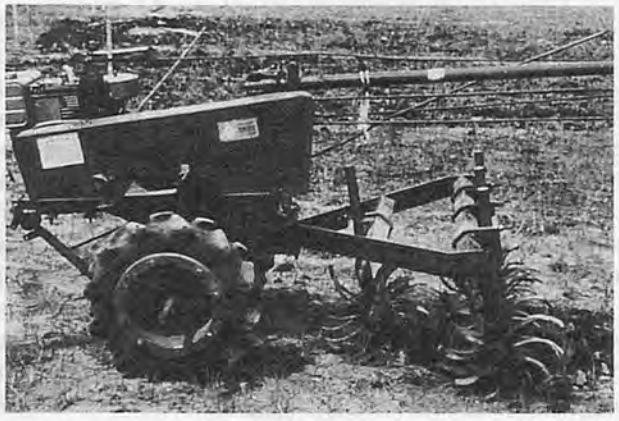


Fig. 3 Rolling weeder.

Table 1 Relative Dry Weight of Three Major Weed Groups and Total Weight of Weeds Growing in Association with Unweeded Dryland IR50 Rice at Different Times of Sampling.[1/] IRRI, 1980 Wet Season

Weed group	14 DAE	28 DAE	42 DAE	70 DAE
		Dry weight (%)		
Broadleaf weeds	0.6 c	1.6 b	3.8 b	0.3 b
Grasses	19.6 b	44.8 a	82.1 a	99.3 a
Sedges	79.8 a	53.6 a	14.1 b	0.4 b
		Total weed weight (g/m^2)		
	58.0	135.0	325.6	633.8

1/ In a column, means followed by a common letter are not significantly different at the 5% level. DAE = days after rice emergence.

Table 2 Total Weed Weight as Influenced by Weed Control Treatments at Various Times of Sampling in Dryland IR50 Rice.[1/] IRRI, 1980 Wet Season.

Treatment[2/]	Total weed weight (g/m^2)			
	14 DAE	28 DAE	42 DAE	70 DAE
Rolling weeder	99.4 a	40.9 bcde	108.0 bc	492.6 ab
High wheel cultivator	49.6 a	33.3 bcde	70.0 bc	313.6 ab
Hoe weeding	53.2 a	36.0 bcde	40.8 cdef	381.4 ab
Hand weeding	158.4 a	12.6 e	42.1 cdef	175.0 bc
Herbicide	140.8 a	134.1 a	217.6 ab	355.6 ab
Herbicide fb rolling weeder	65.8 a	57.2 bc	96.9 bc	367.6 ab
Herbicide fb high wheel cultivator	119.6 a	58.0 bcd	47.4 cde	292.0 abc
Herbicide fb hoe weeding	70.8 a	32.0 de	29.5 cdef	332.0 ab
Herbicide fb rolling weeder + hand weeding in rows	86.6 a	38.5 bcde	63.8 cd	258.4 abc
Herbicide fb high wheel cultivator + hand weeding in rows	54.6 a	21.6 bcde	13.5 fg	130.0 bc
Herbicide fb hoe weeding + hand weeding in rows	55.6 a	34.8 bcde	22.7 defg	220.2 abc
Rolling weeder + hand weeding in rows	96.8 a	47.0 bcd	55.1 cde	246.8 abc
High wheel cultivator + hand weeding in rows	85.2 a	58.8 b	34.2 cdef	145.5 bc
Hoe weeding + hand weeding in rows	66.6 a	17.1 cde	7.5 g	95.6 c
Weed-free check	57.0 a	26.1 bcde	21.1 efg	52.0 d
Unweeded check	58.0 a	135.0 a	325.6 a	633.8 a

1/ In a column, means followed by a common letter are not significantly different at the 5% level. DAE = days after emergence.

2/ fb = followed by, + = applied at the same time.

DAE and then decreased (Table 1).

The dry weights of weeds in all plots at the first sampling (14 DAE) before imposition of inter-row cultivation or hand-weeding did not significantly differ, indicating that the herbicide had no effect on any of the weed groups present at that time (Table 2). At the other sampling times, the highest weed weight was in the unweeded check and the lowest in the plots hand-weeded twice (28 DAE), the plots that were hoe-weeded and then hand-weeded in the rows (42 DAE), and the weed-free check (70 DAE).

At the second sampling (28 DAE), weed weight in all plots, except that which was treated with herbicide alone, was significantly reduced compared to the unweeded check. In most of the inter-row cultivated plots, the weed weight was not significantly different from that in the hand-weeded and weed-free plots. Exceptions were treatments in which weeding consisted of herbicide followed by rolling weeder or high wheel cultivator, and rolling weeder plus hand-weeding in rows, which were inferior to the hand-weeded treatments in controlling weeds. Use of herbicide and hand-weeding in the rows, combined with inter-row cultivation, did not result in a significant advantage over inter-row cultivation alone.

The weed weight 42 DAE (after the second inter-row cultivation) was lowest in the plot that had received a how-weeding plus hand-weeding in the rows. Use of herbicide alone resulted in a weed weight similar to that of the unweeded; while the rest of the treatments had weed weights equivalent to the weight in the hand-weeded plot. At this stage, hand-weeding in rows accounted for an 11.2% increase in weed suppression over inter-row cultivation alone. The percentage suppression of weeds compared to the unweeded check were 92.3 in the plots that were hoe weeded, 86.3 in those that were cultivated with the high wheel cultivator, and 75.1 in those where the rolling weeder was used.

The last weed sample was taken 29 days before crop harvest (70 DAE). At that stage, all the treatments except hand-weeding, herbicide followed by high-wheel cultivator plus hand-weeding in the rows, the hand-hoe plus hand-weeding in the rows, and weed-free check had a weed weight statistically similar to that of the unweeded check. The rolling weeder, hand-hoe, and high-wheel cultivator suppressed weeds 46.2, 59.4, and 65.2%, respectively, while hand-weeding suppressed weeds 74.4%. Hand-weeding in the rows contributed 36.9% to weed suppression at this stage mainly because of the

dominance of *R. exaltata* at the later stages of crop growth.

The time required for two inter-row cultivations using the rolling weeder, high-wheel cultivator, and hand-hoe were significantly lower than the time for two hand-weedings and maintaining the crop weed free (Table 3). Reduction in the time required for weeding was 99.0% with the rolling weeder, 91.0% with the high wheel cultivator, and 90.0% with the hand hoe, compared to that for the plot that was maintained weed-free. Singh et al (1981) recorded less than 0.5% of the time required for one hand-weeding when the rolling weeder was used once. Complete weeding in rows after the inter-row cultivation required almost 1,000 man-h/ha, which was equivalent to 39.3% of two hand weedings.

Yields in all plots were low because the crop suffered drought stress during its vegetative growth, at flowering, and at grain filling. The highest grain yield was obtained from the weed-free check and the lowest from the unweeded check. Inter-row cultivation with the hoe or the high-wheel cultivator when supplemented with complete hand-weeding in the rows resulted in a yield which was not significantly different from that of the weed-free plot receiving four hand weedings. Except for the plot treated with herbicide alone, the remaining treatments which did not differ significantly among each other with respect to yield, yielded significantly lower than the weed-free check and significantly higher than the unweeded check. The yield of the herbicide-treated plot was not significantly superior to that of the unweeded check (Table 4).

The use of a pre-emergence herbicide in combination with inter-row cultivation did not bring about a significant increase in grain yield compared to cultivation alone be-

Table 3 Time Required for Weed Control in Dryland IR50 Rice as Affected by Various Weed Control Treatments.[1/] IRRI, 1980 Wet Season.

Treatment[2/]	Time required (man-h/ha)		
	First operation	Second operation	Total
Rolling weeder	11.2 c	11.2 e	22.4 e
High wheel cultivator	93.6 c	128.8 e	224.4 e
Hoe weeding	134.4 c	123.2 e	257.6 e
Hand weeding	1629.6 a	908.0 a	2547.6 b
Herbicide	4.0 c	–	4.0 e
Herbicide fb rolling weeder	15.2 c	11.2 e	26.4 e
Herbicide fb high wheel cultivator	127.2 c	153.6 de	280.8 e
Herbicide fb hoe weeding	156.8 c	158.4 de	315.2 e
Herbicide fb rolling weeder + hand weeding in rows	583.2 b	545.6 b c	1128.8 c d
Herbicide fb high wheel cultivator + hand weeding in rows	590.4 b	335.2 c d	925.6 d
Herbicide fb hoe weeding + hand weeding in rows	635.2 b	538.4 b c	1173.6 c
Rolling weeder + hand weeding in rows	636.0 b	610.4 b	1246.4 c
High wheel cultivator + hand weeding in rows	929.6 b	552.8 b	1482.4 c
Hoe weeding + hand weeding in rows	613.6 b	540.6 b	1154.4 c
Weed-free check	1604.8 a	973.6 a (950)[3/]	3528.4 a

1/ In a column, means followed by a common letter are not significant at the 5% level.

2/ fb = followed by, + = applied at the same time.

3/ Two additional hand weedings amounting to 512 and 438 man-h/ha at 42 and 56 days after emergence, respectively, were required to keep the plots weed-free.

Table 4. Yield, Weeding Cost, and Return to Weeding as Affected by Various Weed Control Practices in Dryland IR50 Rice.[1/] IRRI, 1980 Wet Season.

Treatment[2/]	Yield (t/ha)	Weeding cost[3/] ($/ha)	Net return to Weeding[4/] ($/ha)
Rolling weeder	0.49 e f	13.44	66.95
High wheel cultivator	0.65 d e	46.04	61.72
Hoe weeding	0.84 c d e	52.04	88.22
Hand weeding	0.73 d e	507.52	–386.07
Herbicide	0.08 f g	57.86	–47.60
Herbicide fb rolling weeder	0.80 d e	71.30	62.12
Herbicide fb high wheel cultivator	0.67 d e	115.16	– 3.98
Herbicide fb hoe weeding	0.65 d e	120.72	– 12.96
Herbicide fb rolling weeder + hand weeding in rows	0.71 d e	291.78	–173.76
Herbicide fb high wheel cultivator + hand weeding in rows	1.07 b c d	243.74	– 64.14
Herbicide fb hoe weeding + hand weeding in rows	0.66 d e	292.30	–182.83
Rolling weeder + hand weeding in rows	0.67 d e	258.24	–147.06
High wheel cultivator + hand weeding in rows	1.28 a b c	306.85	– 91.33
Hoe weeding + hand weeding in rows	1.44 a	231.40	11.49
Weed-free check	1.60 a	705.68	–435.42
Unweeded check	0.02 g	–	–

1/ In a column, means followed by a common letter are not significant at the 5% level.

2/ fb = followed by, + = applied at the same time.

3/ Operational cost of rolling weeder $0.60/h including operator; cost of labor, $0.20/h; spraying cost, $2.10/day; herbicide price, $12.50/*l*.

4/ Price of rice, $171.05/t.

cause of the failure of the herbicide to control the weeds satisfactorily. However, hand-weeding in the rows resulted in significant increase (0.5 t/ha) in yield indicating that, as observed by Diaz et al (1974) and Haswell (1972), weed control within the rows was beneficial regardless of the implement used. However, Singh et al (1981) did not notice such a yield increase when weed pressure was low.

The yield differences among the various treatments were caused by the differences in the amount of weeds growing in the plots. Thus, the yield of plots which received an inter-row cultivation that resulted in fairly good suppression of weeds was equivalent to that of the plot that was hand-weeded twice. There was the additional advantage of savings in labor. Additional weeding in the rows further enhanced weed control and increased yield, but there was a 39.3% increase in the labor required for weeding. There was a significant negative correlation between grain yield and weed weight at different growth stages (Table 5). A weed weight of 144, 273, and 602 g/m^2 at 28, 42, and 70 DAE, respectively, was sufficient to cause complete yield loss.

The net returns to weeding were low due to the low yield obtained on account of moisture stress during crop growth. The net return to weeding was highest with hoe weeding ($88.22/ha), and next highest with the rolling weeder ($66.95/ha). The net returns were highest mainly because of low cost of weeding. These treatments cost 10% and 3% of that required for hand-weeding, respectively. The net return with the high wheel cultivator was $61.70/ha and its cost was 9% that of hand-weeding (Table 4).

Complete hand-weeding as well as weeding in the rows resulted in a net loss because of the large labor requirement and thus, the high cost of weeding. The treatment in which hoe-weeding was done in combination with hand-weeding in rows resulted in a net return of only $11.50/ha even though the yield was as high as that of the weed-free check.

Use of rolling weeder in the herbicide-treated plot resulted in a net return of $62.12/ha. When the high wheel cultivator and hand-hoe were used in combination with the herbicide, a negative return was observed because of the longer time required for weeding compared to the rolling weeder and the negative return to weeding when herbicides alone were used.

Even though yields and the net returns to weeding were low, the potential for using inter-row cultivation as a means of weed control in dryland rice has been demonstrated. The great advantage is the tremendous savings in time with inter-row cultivation whether it be manual or mechanical compared to hand weeding.

Weeds within the crop row still create problems. A significant increase in yield was obtained when these were removed, as was also observed by Curfs (1976). In this experiment, all the weeds within the row were removed. This was extremely time-consuming. Consideration should be given to removal of only the larger weeds (e.g. those as tall as the rice plant) or increasing the seed rate to provide increased competitiveness against these weeds, or both. Such techniques may substitute for the highly labor-intensive techniques presently used by the farmer.

In this trial, the herbicide used performed poorly. Better herbicide performance would reduce or eliminate the need to remove the weeds within the crop row. Unfortunately, there is still lack of a suitable herbicide that will provide good control of some of the weeds such as *C. rotundus* in upland rice.

Further research needs to be done with the equipment used in this experiment and other pieces of equipment locally available or that can be manufactured easily in a country at a price that is acceptable to the farmer. The rolling weeder in this experiment has certain problems; the major one is a tendency to push down the weeds rather than to uproot them. Thus, the weeds quickly reestablish themselves after a rain. Damage to the rice plants also occurs if the rice rows are not straight or evenly spaced. Thus, if mechanical weeding is to be used, there may be need to develop a row seeder and a weeder together to avoid crop damage during weeding.

Table 5 Correlation Coefficients and Regression Equations between Grain Yield and Weed Weight at Different Sampling Times. IRRI, 1980 wet season.

Sampling time (DAE)1/	r	Regression equation2/
14	−0.325	–
28	−0.692**	Y=1.169−0.0081X
42	−0.766**	Y=1.064−0.0039X
70	−0.827**	Y=1.446−0.0024X

1/ DAE = days after emergence.

2/ Y = rice yield (t/ha) at 14% moisture, X = total dry weight of weeds (g/m^2).

** Significant at 1% level.

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Electrostatic Spraying with a Knapsack Sprayer

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Abstract

The possibility of installing the electrostatic charging methods of spray liquid with small sprayers has been investigated. The usability of these sprayers with different variable parameters has been studied.

The influences of different charging methods, voltages and number of electrodes on the amount of electrodes were observed.

The results obtained by using the electrostatic charging methods were compared with the results obtained by the conventional method of spraying. The distribution of deposition has been studied in three conditions: laboratory, field and green house.

The original state of the sprayers were kept constant. The electrostatic charging unit was an additional input into the sprayers. Five sprayers were used in the experiment. Similar results with all the sprayers were obtained. The results obtained by using a knapsack sprayer with an air shear nozzle has been described.

Introduction

Proper application techniques in spraying may protect the surrounding atmosphere and the nearby water bodies from pollution. The use of chemical for plant protection has been increased throughout the world. Because of a worldwide increasing awareness of the atmosphere and the water bodies, chemical plant protection methods are nowadays frequently called into question.

The aim of the present application technique is to make a significant reduction in the amount of spray-liquid and active ingredients using the smallest possible technical input for reducing the drift and simultaneously to increase the target-deposition and, thereby, achieve a maximum possible biological effectiveness.

The use of the electrostatic charge in the spray-liquid increases the overall target-deposition (1, 2, 3, 4, 5, 6, 7, 8). With traditional sprays, sometimes only 20% spray-liquid reaches the target (9) and that can be increased up to 80% by using electrostatic spraying and require 50% less chemical ingredients (10).

Electrostatic force on small droplets is more prominent than the gravitational force and drift can be reduced by electrostatic charging of spray droplets (11, 12). Uncharged droplets smaller than 100 μm will drift to an appreciable distance under most meteorological conditions (13).

Electrostatic Charging Methods

There are three electrostatic charging methods which may be successfully applied for the production of charged droplets in plant protection machines (14, 15, 16, 17). **Fig. 1** describes the charging method. In the contact charging system (1b), the high voltage is directly connected to the whole spraying system to the liquid, whereas with the corona charging system (1a), the spray particles are charged in the corona, produced by the high voltage around sharp electrodes. In the case of the induction charging method (1c) the droplets are charged in an electric field. This system requires insulation between conductive liquid and electrode, which can be realized by an air stream of high velocity. Contact and influence charging, usually needs new and expensive constructions of spraying machines, corona charging systems can be mounted at conventional sprayers. In the case of the corona charging method, the number of electrodes may be 1 to 4 or more.

For the safety of operation, the sprayers should be grounded during spraying and an insulation should be provided between the gap of the sprayer and the high voltage generator. A 12-volt battery or a 12-volt DC generator in hand or shoulder-carried sprayers may be used to supply the input voltage to the high voltage generator. For a wheel barrow type sprayer, a 12-volt car battery may also be used.

The functions and details of a knapsack sprayer's head using the corona charging method are shown in **Fig. 2**. A two-stroke petrol en-

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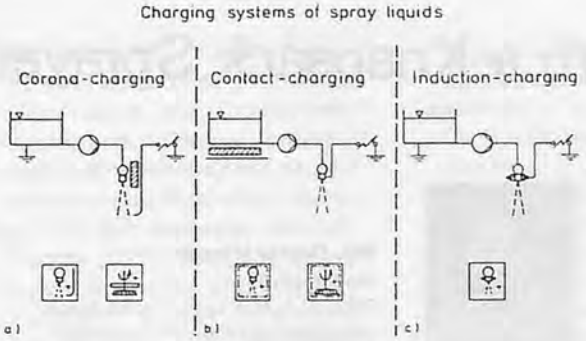


Fig. 1 Electrostatic charging system with symbols.

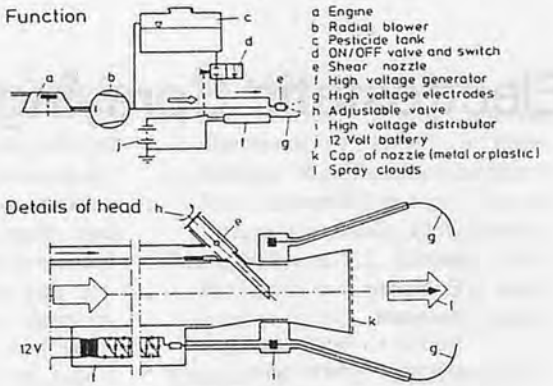


Fig. 2 Schematic diagram of functions and details of experimental sprayer with an air shear nozzle using the corona charging method.

gine (a) is used to run the radial blower (b). At maximum throttle, the engine rotates at 6200 rpm. Due to direct coupling, the rpm of the radial blower is identical to the rpm of the engine. The maximum air-velocity supplied by the sprayer at the spraying point is 30 m/s. This sprayer delivers air 598 m^3/h. The amount of flow-rate through the nozzle can be controlled by manual adjustment (h). The output through the nozzle varies depending on the nozzle numbers. The pesticide tank (c) has a capacity of 12 litres. The total weight of the sprayer with full tank-pesticide is nearly 20 kg. With one filling, this sprayer can be used for about 30 minutes in the field. Spray-liquids from the tank to the nozzle can be controlled by means of a two-way-control valve(d). The high voltage generator (f) furnishes the high voltage (70 kV) to the charging electrodes (g) through the high voltage distributor (i). A 12 volt DC is supplied and directed to the high voltage generator (HVG). This can be furnished from a 12 volt battery (j) or from 8 x 1,5 volt dry cells or from a 12 volt DC generator.

The electrical capacity of the high voltage circuit is very small and also there is very low current flowing in the circuit. As a result, the problem of the electrical hazards is automatically solved. It is possible, too, to charge the spray-liquid by using the contact charging method. The contact charging method, however, requires very good insulation. This is very costly and more advanced technology is needed. Therefore, this method is normally not used for knapsack sprayer to charge sprays. The corona charging method, on the other hand, can easily be installed with this sprayer.

Deposition Study in the Laboratory

A steel pipe of a diameter of 10.85 cm and of a length of 2.2 m was chosen as a target-object. Filter papers with surface area of 102 cm^2 were used for the collection of spray droplets. Filter papers were wrapped around the steel pipe 10 cm apart from each other. Each filter paper was divided into 4 equal parts. They were marked at the nozzle by front, behind, left and right side, in order to know the distribution of deposition around the target-object.

All targets were sprayed with standard tracer preparation consisting of 0.2% BSF (brilliant sulphoflavine) diluted in tap water. It was assumed that the tracer residue on the target would be analogous to the pesticide active ingredients in the spray. Spray deposition was reclaimed from the targets by a standard wash procedure using distilled water. This contained 0.03% methanol. A self-balancing Turner Fluorometer was used to quantify the spray deposition.

The deposition on the surface of a target-object was computed by using the following formulae:

$$D = (CF/100)\ (V_L\text{-}FDR)/A_{FL} \quad (\mu g/cm^2) \quad ...(1)$$

$$RD = (D \cdot 100)/(Q_a.C) \quad (\%) \quad ...(2)$$

$$Q_a = (600\ q)/(b \cdot V_F) \quad (1/ha) \quad ...(3)$$

where,

- D deposition, $\mu g/cm^2$
- CF concentration factor, $\mu g/ml$
- V_L volume of liquid used for washing out the spray residue, ml
- FDR fluorescent dial reading, number
- A_{FL} surface area of the target-object, cm^2
- RD relative deposition, %
- Q_a volume of liquid applied, 1 l/ha = 1 $\mu g/cm^2$
- C concentration of solution, %
- q discharge through the nozzle, l/min
- b width of spraying, m
- V_F driving velocity of a sprayer, km/h

The liquid flow rate (q) through the nozzle of a small sprayer is almost constant for one spraying height because of gravity feed. The working width (b) is also constant for a particular height of spraying. The amount of spray-liquid needed per acre basis depends upon the ground velocity (V_F) of the sprayer. All the small sprayers are either hand- or shoulder-carried.

Farmers carry these sprayers themselves. Their walking speed varies, on the average, from 1.5 to

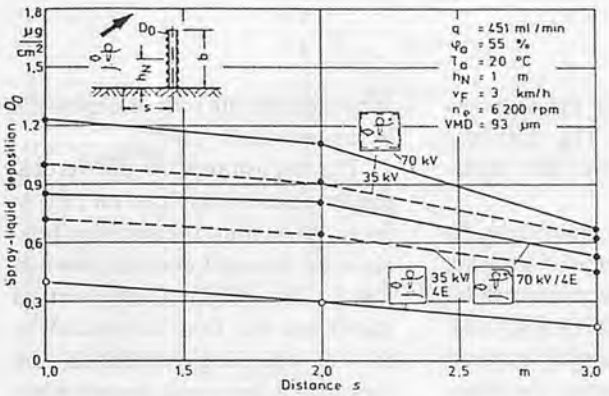


Fig. 3 Deposition of spray-liquids of a knapsack sprayer having an air shear nozzle using different charging systems and voltages at different distances from the spraying nozzle.

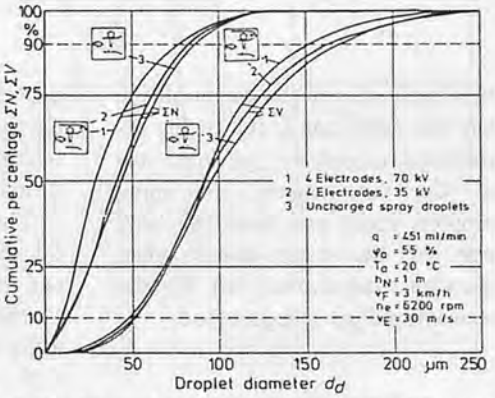


Fig. 4 Droplet spectrum of sprays of a knapsack sprayer with an air shear nozzle using different operating conditions.

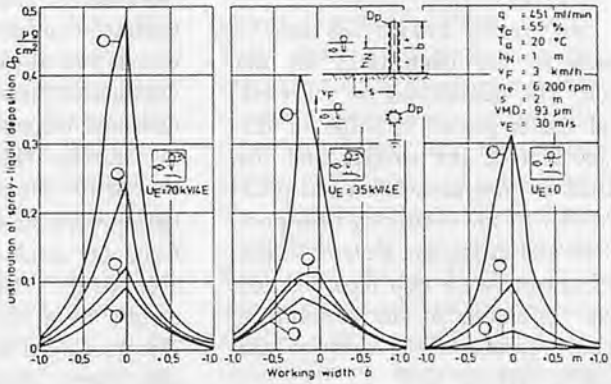


Fig. 5 Distribution of spray droplets around target-object. A knapsack sprayer with an air shear nozzle was used. The corona charging method with different charging voltages and traditional method of spraying were applied.

3 km/h. On this assumption, the laboratory experiments were carried out at a ground velocity between 1.5 to 3 km/h. A test stand was used to provide the desired height and driving velocity at the time of experiment.

The experimental conditions and the results of a knapsack sprayer having an air shear nozzle using the different charging methods are shown in **Fig. 3**. The contact- and the corona- charging method and the conventional spraying method were employed in the experiments and their effects were investigated. The depositions were measured at an interval of 1 m up to 3 m from the spraying nozzle. Depositions were measured with charging voltages of $U_E = 0$; (uncharged) 35 and 70 kV. In the corona charging method 4 electrodes were used. The highest amount of deposition was obtained by using the contact charging method. The contact method was more effective than the corona charging method. The charging voltage had also influence on the amount of deposition. By using the contact and the corona charging methods, the depositions increased by about 1.17 and 1.3 times when the charging voltages were increased from 35 kV to 70 kV. The deposition obtained by using the electrostatic charging method was at least 3 to 4 times higher as compared to the deposition obtained when the conventional spraying (without liquid charging) method was used.

By using the contact charging method, the spray droplets were more fully charged than the corona charging method and helped to promote better deposition on the desired target-object. In using all the charging methods, the depositions decreased without increasing the horizontal distances. The deposition within 1 to 1.5 m from the sprayer was more or less equal. The gravitational forces on the tiny droplets in this region were negligible in comparison to the electrostatic forces. These tiny droplets followed the path of the electric lines of forces and helped increased deposition.

The droplet spectrum of sprays of this sprayer was determined under experimental conditions (**Fig. 4**). The droplets below the range of the VMD were effectively controlled by the electrostatic forces and deposited nearby the surrounding of the nozzle. The big droplets settled down within 1 m of the nozzle and the comparatively smaller droplets were carried to a far distance due to the air velocity of the sprayer.

The distribution of deposition around the target-object at a distance of 2 m from the sprayer nozzle is shown in **Fig. 5**. The corona charging method (either applying 35 kV or 70 kV and 4 electrodes) and the conventional spraying method were employed in the experiments. The deposition on the front side of the target-object was at least 2 to 3 times higher than the deposition recorded on the sides. A considerable amount of deposition was obtained on the back side of the target-object when the spray liquid was charged by using the electrostatic charging method. But in the case of the conventional spraying method, no deposition was recorded on the back side of the target-object.

Due to the nature of curves of the electric lines of forces, the tiny spray droplets are accumulated on

the back side of the target-object. On the other hand, due to the obstruction caused by the front side of the target-object, the spray droplets could not reach the back side of the target-object when spraying was carried out by the conventional spraying method.

Deposition Studies in the Field

An area of 200 m^2 was used to measure the depositions on the soil. The depositions on the vertical stands placed at different distances from the sprayer and the drifts at three places were recorded. Parallel to the measuring of depositions and drifts, the meteorological parameters were also recorded and the conditions of the atmosphere were forecast by means of the stability ratios.

Spraying was carried out when the wind direction was convergent with the spraying directions. An additional carrier air stream was supplied and directed to aid droplet transport and to improve the electrically charged droplets deposition onto the target-object. The corona charging method was applied to charge the spray liquid. An axial blower which supplied an air volume of 45000 m^3/h was used to have a drift air velocity at the sprayer from 3 m/s. Filter papers of diameter of 4 cm were used to collect the spray deposition. The filter papers were placed on the nails having head of 4 cm. The drift was registered by using the drift monitoring equipments.

The spray-liquid depositions on the soil in the direction of spraying and measured under experimental conditions are shown in **Fig.6**. By using the corona charging method with a carrier air stream, the deposition was higher than under other operating conditions. In using the electrostatic charging method, the highest deposition was recorded within 1 m of spraying nozzle. The deposition became less and less as distances increased from the spraying nozzle. The charged droplets looked for the nearest zero potential for deposition. The electrostatic force on small droplets governed their path of flight to only a few meters from the spraying nozzle. The uncharged small droplets, however, were carried many meters away from the sprayer untill the droplets touched the ground. The horizontal distance of deposition was about 15 m by using electrostatic charging method. When a carrier air stream was used with the conventional spraying method, the horizontal distance of deposition extended more than 20 m.

In using the electrostatic charging method, the spray droplets were deposited in short distances within the test field. When the conventional spraying method was used, the spray droplets were carried beyond the test field. Thus, they reduced the overall deposition in the test area.

The depositions on the vertical stands placed at an interval of 5 m up to 20 m from the spraying nozzle were recorded and are shown in **Fig. 7**. The height of the vertical stands was 4 m from the ground. In all the operating conditions, the depositions decreased sharply when there was an increase in height and increase in the horizontal distances from the spraying nozzle.

This vertical deposition actually gives an idea of the drift at a place. When using the corona charging method, the deposition on the vertical stands was higher up to the horizontal distance of 10 m. From then on the deposition was higher when using the conventional spraying method. Using a carrier air stream with the corona charging method, the deposition was higher up to 15 m and from then on the deposition was higher using the conventional spraying method. Therefore, in calm air, when electrostatic charging is used, the distance of deposition can be controlled within short distances.

During spraying operation, a large amount of spray-droplets was lost through drift. An investigation was carried out to establish the extent to which drift reduction would be practically possible with electrostatic charging. Iso-kinetic drift monitoring equipment was used to record the spray droplets drifted under experimental conditions.

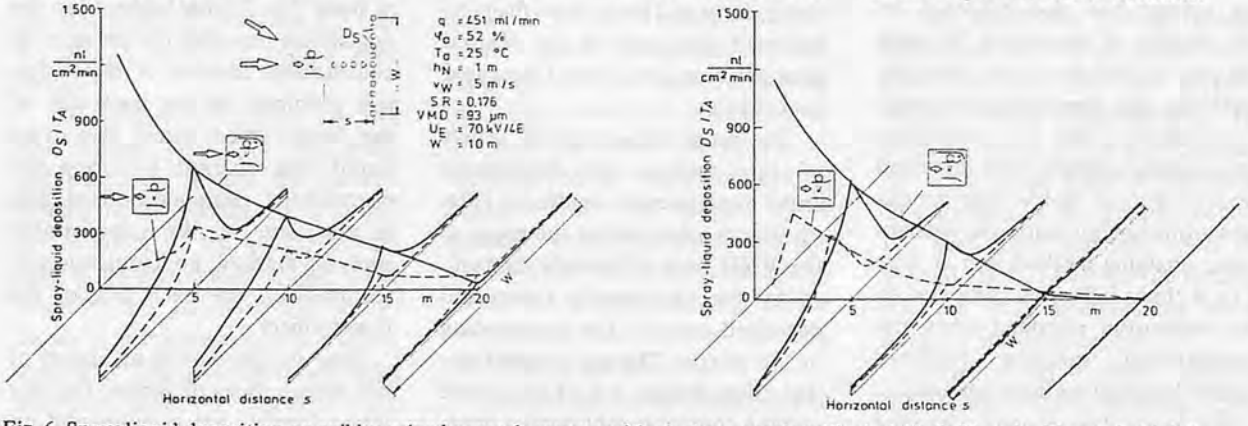


Fig. 6 Spray-liquid deposition on soil by using knapsack sprayer with air shear nozzle with air drift (left) and without air (right).

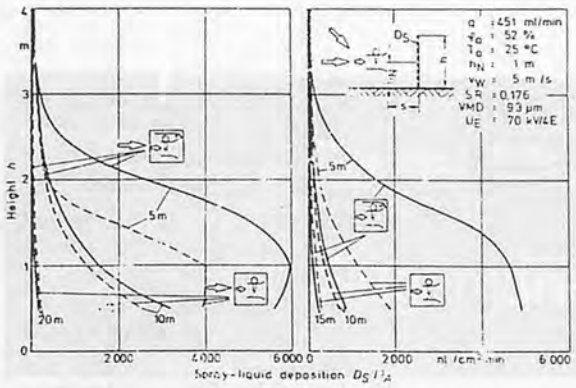


Fig. 7 Distribution of spray depositions on vertical stands placed at different distances. Different operating conditions were applied.

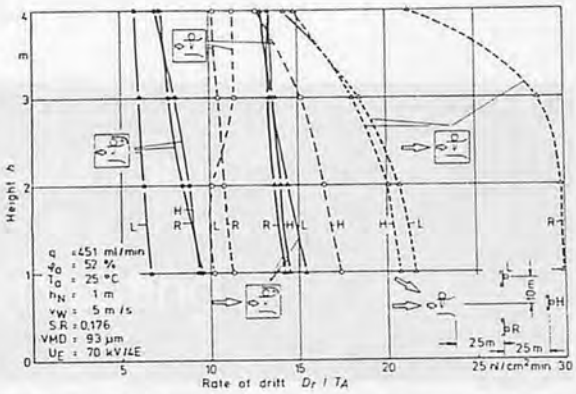


Fig. 8 Profiles of drifts at different operating conditions. A knapsack sprayer with an air shear nozzle was used.

The drifts were measured at three places: at 25 m (10 m to the left and to the right from the centre line of spraying, designated by L and R) and 50 m away from the spraying point (designated by H). The drifts were recorded up to a height of 4 m from the ground. The experimental results are shown in Fig. 8.

In all four operating conditions, the minimum drift was obtained by using the corona charging method (without carrier air stream). The drift was considerably greater without electrostatic charging and showed an increase with greater distance and height. The drift was clearly reduced to an approximate constant value with electrostatic charging of the spray droplets. This reduction in drift was due to the increased deposition in the test area.

Deposition Studies in Green House

Plant protection in green houses is very important due to their wide scale use throughout the world. A plastic house was chosen to perform the experiments. The area inside the plastic house was 8 x 30 m. (Fig. 9). Filter papers of diameter of 4 cm were used to collect the spray deposition.

Depositions were measured on the soil, on the metallic frame of the house and on the inside cover of the plastic. The depositions on the soil were collected from the filter papers placed on the nails. During the experiment, the temperature and the relative humidity were recorded.

The average depositions on the soil, on the metallic frame and on the plastic cover are shown in Fig. 10. The corona charging method and the conventional spraying method were applied.

By using the corona charging method, the average deposition on the soil was higher than the deposition obtained by the traditional spraying method. When electrostatic charge was applied to the spray-clouds, the deposition on the conducting medium (metallic frame) was higher than the one obtained on the nonconducting medium (plastic cover). The plastic cover here acted as a condenser. When the charge droplets came into contact with the plastic, they repelled and as a result, the deposition on the plastic cover was lower when the electrostatic charging method was used as compared to the conventional spraying method. With the conventional spraying method, the tiny droplets which were floating in the air were deposited on the plastic cover. On the other hand, the charged tiny droplets sought the nearest zero potential at the time of flight.

The distribution of spray droplets under experimental conditions is shown in Table 1.

By using the electrostatic charg-

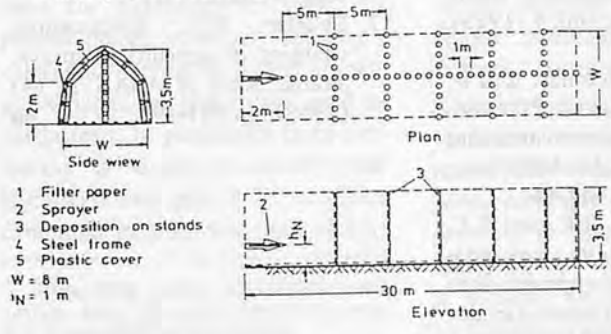


Fig. 9 Experimental setup in a plastic house.

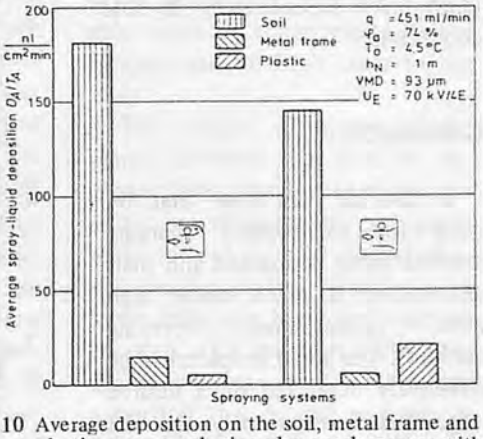


Fig. 10 Average deposition on the soil, metal frame and plastic cover employing a knapsack sprayer with an air shear nozzle. The corona charging and the traditional methods were used.

Table 1 Balancing of Spray Droplets Emitted from a Knapsack Sprayer Having an Air Shear Nozzle under Different Operating Conditions

Method of charging	on soil (%)	on plastic cover (%)	on metal frame (%)	on vertical stands (%)	suspension in air (%)
Corons charging method (70kV)	94	5	0.55	0.34	0.11
Traditional method	77	22	0.33	0.21	0.46

ing method, the overall efficiency of deposition on the soil was better than by using the conventional spraying method. Only a small amount of spray-liquid was not found during the collection of samples. This may be due to some small droplets which were floating and remaining in the air.

The depositions on the soil in the green house were higher as compared to the depositions obtained in field conditions. In the field conditions, a considerable amount of spray-liquid drifted to the adjoining unwanted places, due to the prevailing air current. On the other hand, all the spray droplets were deposited in the plastic house. Only a very small fraction of spray liquid could not be traced. They might have been absorbed by the wind outside, or they might have been suspended in the air. This amount was very small (less than 1%). The amount of spray droplets which was deposited on the metal frame and on the plastic cover would certainly have drifted away in field conditions.

Conclusion

It can be concluded that by using the electrostatic charging method, spray deposition and their distribution is much better than with conventional spraying methods. The small droplets can be effectively deposited on a desired target and simultaneously, the drift can be reduced to a great extent to solve problems of chemical plant protection. The electrostatic charging method can be successfully installed in small sprayers.

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Partial Mechanization of Sugarcane Harvesting



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Abstract

A sugarcane harvester, rear-mounted on tractor, designed and developed at the Indian Institute of Sugarcane Research, Lucknow, cuts cane flush with ground level and windrows the harvested stalk. It harvests 2 ha of standing crop per working day of 8 h. The design is light in weight, compact and easy to operate with a 35 hp tractor. Field trials continue to enable the machine to adjust to varying soil and crop conditions.

Introduction

A hectare of sugarcane crop of 70 t normally requires 150 man-days for harvesting in India. In several places, especially sub-tropical India, harvesting is free of cost in exchange for green tops, used as cattle feed. In peninsular India harvesting is largely done by paid labourers who give 0.5 t of clean cane/man in a working day of 8 h. Payment is based on weight of cane harvested and the rates vary with place and crop season. In some parts of peninsular India the responsibility of harvesting rests with sugar mills. They engage labourers, usually migrants, or pay harvesting charges to the farmers.

About 3.4 million ha of sugarcane was harvested in 1982-83 largely between November to May, the crushing season. In Tamil Nadu in tropical India, a short season in July and August also, between the two monsoons, is in vogue. In mill areas, harvesting, cleaning and supply at purchasing centre is done by the farmer on receipt of a supply permit from the sugar mill which specifies date and quantity of cane to be supplied. To meet limited labour availability on time, the farmers continue harvesting and stocking sugarcane slowly and supply when they get the supply permits. This results in staling of cane, consequent decline in sugar recovery is, therefore, discouraged. However, the fact remains that it is difficult to get enough labour to harvest a required quantum of canes and supply them within 12 to 20 h of getting a permit.

Primarily, other time-bound agricultural operations compete for limited labour force. These are paddy and maize harvesting, autumn planting of sugarcane and potato, drilling of wheat, mustard and other rabi crops, and harvesting of these crops in the middle and towards the end of the crushing season. In areas like the foot hills of sub-tropical India, where plantations are large, yields high and manual labour comparatively scarce, the timely harvesting is a perpetual problem. A simple sugarcane harvester windrower appears to provide scope of some respite to the farmers and of fresh canes to the mills.

The quality of harvesting depends on how close it is to the ground level. In manual harvesting a cutter has to stoop low enough to make the cut close to ground level, yet manage a full swing on the knife with one hand and support the stalk with the other. Hired help generally leaves a stump of 2-10 cm, a portion that is rich in sugar. A 2.5 cm stump cane accounts for, on

Note: Help received in fabrication and testing from Mr. P.R. Singh, Scientist S-1 is gratefully acknowledged.

an average, about 1 t/ha of cane, or, the equivalent of one quintal of sugar. The former is a loss to the farmer and the latter, to the industry. These losses can be minimized by adopting suitable harvesting machine.

Mechanized Harvesting

Where sugarcane culture is fully mechanized, harvesting is done with whole cane or chopper harvestors. The standing crop is first put to fire to burn dried foliage. The machine then cuts the stalks at base and simultaneously detops as well. Harvested stalks are either windrowed and collected later or chopped into pieces which pass through two powerful blasts of air to remove adhering trash and dropped in to a bin moving along side. Harvesting is precisely turned to the movement of bins, its unloading at mills and crushing. Mobile field workshops are established. Delay or hold up at any station fouls up the system and is expensive.

Burnt cane deteriorates fast in terms of recoverable sugar, chopped cane more so. It may result in sharp drop of sugar recovery with passage of time. It may create problems in processing, too, due to formation of gums, dextran and pentosans. Such harvesters are designed to suit large plantations, swift transport and unloading. A high level of mechanical and management efficiency is imperative.

Sugarcane breeding and crop husbandry suit these machines. One such machine was imported and tried in a new cooperative venture in Zira (Punjab) in the 1981-82 season and soon given up due to high trash content in cane supplied to mills, loss of cattle feed and other problems in operation.

Small and scattered fields limit the use of big harvesters. All the same, harvesting is gradually becoming a serious bottle-neck in India too, with declining availability of labour and intensive cropping system.

A simple tractor operated single row harvester was designed and fabricated at this Institute (2). Based on its field performance it was modified as reported here. It is rear mounted on a 35 hp 4-wheel tractor, cuts cane flush with ground level and windrows it. Cut canes are collected by labourers, detrashed, detopped and stacked. Its output is about 2 ha or 150 t of cane per day, as obtained in trials conducted at the Institute's farm.

Basic Design

The principal components of the harvester are shown in **Fig. 1**.

Framework – The frame is made of mild steel angle iron, provided with three point linkage, for mounting behind a tractor. It is strengthened by cross supports. Two gauge wheels balance the equipment while in operation and adjust the height of the base cutter.

Drive System – The drive to the base cutter is provided from tractor power-take-off shaft, with standard 540 rpm at 1500 engine rpm. The drive from tractor PTO shaft is taken to a standard tractor pulley, through a telescopic shaft and cross joints. Power from standard pulley is transmitted at right angle to left by a pair of bevel gears in the pulley. Speed is increased to 1000 rpm by having the gear-teeth ratio at 1:2. The drive to rotating base cutter, positioned vertically downward is given by an auxiliary

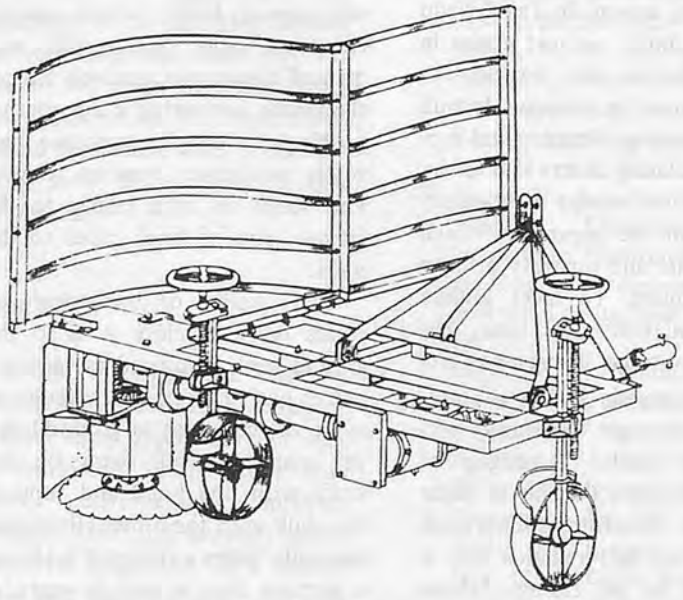


Fig. 1 IISR sugarcane windrower-harvester.

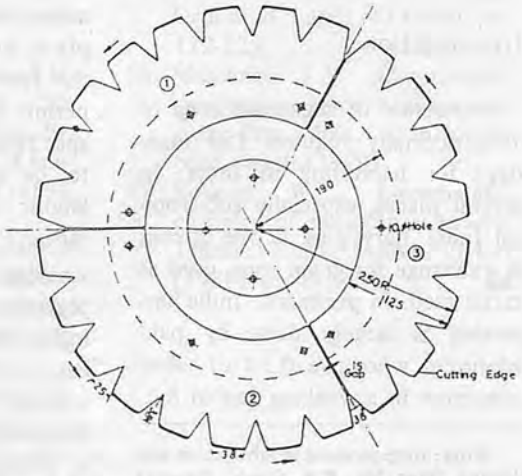


Fig. 2 Cutting disc of IISR sugarcane harvester.

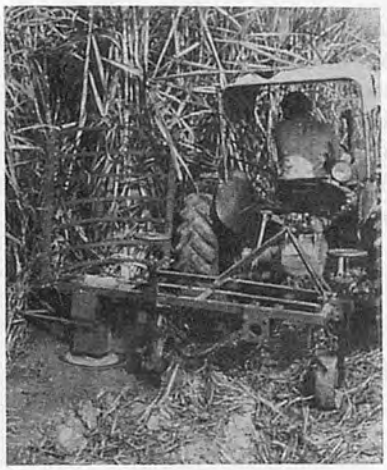


Fig. 3 IISR sugarcane harvester in operation.

gear unit with 21 and 28 teeth, respectively, on driving and driven bevel gear, thereby giving a rotational speed of 750-800 rpm in counter-clockwise direction.

Base Cutter – The cutting disc (Fig. 2) is 500 mm diam. made of high carbon steel with cutting edges coated with wear resistant hard material. It consists of three cutting blades, each blade having 10 trapezoidal shaped cutting elements. The base cutter cuts stalk flush with ground level. The height of cut is adjusted by the gauge wheel and hydraulic controls of the tractor. A guard is provided over the base cutter for the safety to workers and efficient windrowing of canes.

Pusher Guard – A pusher guard made of mild steel flats is provided. It helps in harvesting moderately lodged crop and windrowing of cane.

The specification of the IISR sugarcane harvester Model 2 (Fig. 3) details of which are:

Type	Single row tractor mounted windrower harvester.
Source of power	4-wheel 20-25 hp tractor with PTO shaft and hydraulic control.
Total length	1680 mm
Total width	610 mm
Total height	520 mm
Total weight of harvester	2.90 quintals
Total weight with tractor (M.F. 1035)	18 quintals
Diam. of base cutter	500 mm
Speed of rotation	750-800 rpm in counter clock-wise direction.

Drive system

	Driving gear	Driven gear
Standard tractor pulley		
Number of teeth	22	11
Outer diam.	110mm	60mm
Auxiliary gear unit		
Number of teeth	21	28
Outer dia.	110mm	175mm

Economics of Operation

The harvester was tested at the Institute's farm to evaluate its functional performance and economics of operation. The results of the preliminary trials are summarized as follows:

a) Mechanical harvesting

1. Crop parameters

Variety	Co 1148
Area	1 ha
Row length	185 m each row at 90 cm spacing
Average yield	60-70 t/ha
Crop condition	Moderately lodged

2. Machine parameters

Travelling speed	4.2 km/h
Time taken to harvest one row	3 min
Non operating time	1 min/row
Time taken to harvest one hectare of crop	4 h
Total cost of operating the machine with a 35 hp tractor for a period of 4 h.	Rs. 120.00

3. Labour requirement

Collecting cane for removing dry leaves and green top	2 man-days
Detopping, detrashing and stacking taking over capacity as 6 quintal/man/day	120 man-days
Total labour cost taking wages as Rs. 9/man/day	Rs. 1098
Total cost of harvesting one ha of sugarcane crop with 7 t of cane/ha	Rs. 1218
Cost of harvesting per quintal of cane taking an average of yield of 70 t/ha	Rs. 1.74/quintal

b) Manual harvesting

Labour requirement cutting 23 man-day (Average capacity is 30 quintals/man/day)

Detopping, detrashing and stacking	120 man-days
Total labour cost @Rs.9/man/day	Rs. 1287
Cost of harvesting per quintal of cane	Rs. 1.84
Saving in machine harvesting	Rs. 0.10/quintal
Saving in machine harvesting over manual	

harvesting Rs. 70/ha

Result and Discussion

The IISR single-row, tractor-mounted, PTO shaft-operated windrower harvester is sturdy and compact. It cuts cane flush at ground level. The harvested material is windrowed alone. The rows of cane are collected by labourers who remove dry leaves and green tops. The preliminary trials show the following features:

a. It reduces labour requirement by about 20 man-days/ha. This labour can be gainfully employed for other time-bound agricultural operations.

b. Machine-harvesting saves Rs. 0.10 per quintal of cane harvested. In higher tonnage crop, the economics will be more favourable.

c. The drudgery of cutting operation which is burdensome for some cane varieties that have spines such as Co 7717, is avoided in machine harvesting.

d. The cutting by machine is close to the ground level. Besides giving higher tonnage and better overall sugar recovery, an additional operation of suitable shaving is not necessary in case ratoon is to be raised from the harvested field. In manual harvesting stubble shaving operation is essential for raising a good ratoon crop. The machine can work equally well in moderately lodged crop.

A battery of harvesting machines can be managed by private enterprenuers, cane societies or even sugar mill. They can provide it as custom service on payment, which cooperative cane societies or mills can adjust against cane price. This will permit scheduling of sugarcane harvest effectively in 150-170 days of crushing season. Should this be done by the mill, production of sugarcane, calender of supplies, harvesting and its crush within minimum laps of time would be feasible and result in better overall production with same inputs.

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AMA ABSTRACTS AND INDEX, 1971–1980

— A Key to Wealth of Information —

As the AMA enters its 13th year of publication this year, the Editorial Staff deems it appropriate to commemorate the event by publishing "Abstracts and Index 1971-80" in May, 1983 for only ¥2,000 a copy, including sea mail postage.

During the decade 1971-1980, more than a thousand articles were received by AMA from readers and co-editors. Over 600 of these contributions were published from which the abstracts and index in various aspects of agriculture and agricultural mechanization in developed and developing countries were arranged for use as a handy reference by students, government officials, ressearchers and academicians interested in agriculture and agricultural mechanization. For example, at a glance, the abstract and index tell about the content of the article, author and AMA issue number. The publication form is A3 size (18.5 cm x 21 cm) 82 pages.

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A Study of Traditional and Mechanized Systems for Maize Production in Nigeria



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Abstract

A recent study undertaken to evaluate the appropriate systems of maize production in a community farm project is presented. Traditional and selectively mechanized systems were compared on the basis of timeliness and profitability. A systematic selection of farm equipment was made to enhance farmer's income in the project area. Additionally, the paper established that the optimum farm size a farmer can adequately cultivate in the Nsukka area for maize production is limited to 0.095 ha. The same farmer can conveniently increase his cultivated area to 16 ha if he is encouraged to use tractor-powered ridger and planter either on a shared or hire basis.

Introduction

Agriculture in Nigeria is still small-sized, individualistic and predominantly hand-operated. The unit of land cultivated by an average farmer rarely exceeds 5 ha. Most of the essential production inputs are grossly insufficient, inefficiently distributed and poorly utilized. This state of affairs in the agricultural sector has given rise to inadequate production of food for the rapidly expanding Nigerian population. It has also contributed to the scarcity of agricultural raw materials for the Nigerian industry.

One of the major factors for increasing agricultural production is the effective introduction of mechanization inputs in farming. Mechanization, however, does not necessarily increase yield per unit area but should increase the overall productivity by enabling the farmer to plant crops on time and hence more crops per year at a lower cost of production (Anazodo, 1980). Mechanization, therefore, provides an opportunity for the farmer to intensify his farming. On the other hand, a small farmer needs to intensify his farming to justify mechanization. This apparent vicious circle in the mechanization of small family farms calls for a "integrated package approach" to the solution of the low productivity of Nigerian family farms. It also calls for a sound knowledge and appreciation of the socio-economic environment of the rural farmer (Anazodo, 1982 a, b).

A promising effort towards the adoption of the integrated package approach in the assistance of rural farmers to produce more agricultural products is the establishment of "agro-service centres" in various communities of the country by the Federal Government. In these centres, farmers are provided essential agro-technological inputs at reasonable costs. Government extension officers are also available at the centres to assist in teaching the farmers to improve their techniques for achieving higher agricultural production. The same underlying principle has also motivated the Faculty of Agriculture of the University of Nigeria, Nsukka, to re-initiate in 1972 a pre-war rural development programme at Okpuje, 18 km northwest of Nsukka. The overall aim of the "Okpuje Project" is to help activate the dormant economy of the community and to improve the living conditions of the people through increased production of crops and livestock as well as improved nutrition (Okoye, 1983).

The objective of the study which is briefly reported here was to evaluate the possibilities of introducing mechanization inputs in the production, processing and storage of the major crops grown by the Okpuje community. Improvement on

Acknowledgement: The author wishes to acknowledge the contribution of Mr. E.I. Obiji who assisted in the conduct of the field investigation and in the analysis of data as part of his final year project for the degree of B. Eng. The interest shown by Mr. D.G. Ibe of Farm Operations Section of the Faculty of Agriculture is also gratefully acknowledged. The study was partially funded by a Senate Research Grant from the University of Nigeria, Nsukka. For this, the author is grateful.

the farmers' income; timeliness of operations and the appropriateness of the selected mechanization system were the main considerations in the study. This paper deals only with maize production. Subsequent papers will cover maize and cassava storage and processing, as well as rural infrastructural development.

Research Methodology

The study involved a field investigation which was conducted between September 1982 and April 1983. It dealt mainly with the evaluation of the possibilities for introducing tractor-operated farm equipment for selected operations which have comparative economic advantages over the traditional hoe system. The optimum size of farm was determined for the traditional system as well as for the selectively mechanized system in the case of the farmer who cultivates maize as a sole crop. Furthermore, a set of equipment was selected for the Okpuje farm project with a total farm size of 252 ha.

Several visits were made to the project area. Data were collected from personal interviews with some of the farmers at Okpuje. Some questionnaires were prepared for this purpose. Available documents and literature on Okpuje farm project were reviewed. From these the existing agricultural activities in the community were noted; the techniques and technology currently adopted were identified; the state of infrastructural facilities was observed; the storage and processing methods and systems in use were monitored; the extent of communal lands available for agricultural use was determined (Table 1); the population and population distribution of the community were recorded (Table 2); the yields of crops as well as the market prices of relevant agricultural production inputs and outputs were estimated; and other relevant information were obtained. Details of these are presented elsewhere (Obiji, 1983).

Table 1 Jointly Used Agricultural Communal Lands in Okpuje

Name[1]	Location[2] (km)	Size[3] (ha)	Average number of farmers using the land
Umualaji	5	1,000	40
Eziagu	6	1,200	38
Ogbo Okpuje-ani	3	800	42
Aka Utala	3	1,000	35
Ogbogbo	4	1,100	41
Agu Achala	5	1,400	45
Amanyi Achala	4	900	39

Remarks: 1) Names of communal lands. Each communal land is owned by a kindred. Thus Okpuje consists of seven kindreds. 2) Estimated distance from the house belonging to the Chief of Okpuje which is situated opposite the main village market. 3) Size estimated by a community leader by comparing each communal land with the land allocated for the Okpuje Community Project (252ha)

Table 2 Percentage Distribution of Population of Okpuje, by Age and Sex (1974)

Age group (Yrs.)	Male (%)	Female %)	Total (%)	Sex ratio
0 – 14	45.0	43.9	44.5	100
15 – 64	49.0	54.1	51.4	98
65 & above	6.0	2.0	4.1	325

Source: Interim Report on Faculty of Agricultural Science Co-ordinated Rural Development Programme, University of Nigeria, Nsukka. 1974.
Note: The estimated total population of Okpuje community was 17,000 in 1974. Source as above.

Data on farm machinery performance and costing were assumed from those established in a previous study of tractor and equipment hiring services in Anambra, Imo, Rivers, Bendel and Ogun States of Nigeria (Anazodo, 1982c). There were no such information specifically available for Okpuje.

Theoretical equations for determining the optimum size of equipment and optimum number of equipment were based on the procedures developed by Hung (1970) and Chancellor (1968). The calculation of drawbar power was made from the empirical equation presented by Culpin (1976).

Results and Discussions

Determination of Critical Time

It is well recognized that the time of planting maize in regions that have wet and dry seasons is very important. The advantages of early planting of maize are well documented, especially in North America (Leonard and Martin, 1963; Delorit et al, 1974; Adrich et al, 1975). In the tropics, early planting of maize either immediately before rains are expected to begin, or promptly after the first rains, characteristically produce highest yields (Eberhart and Sprague, 1974).

The optimum date or period for planting corn depends on many climatic and environmental factors. In the rainforest zone of Nigeria, the most important factors are rainfall, solar radiation, soil conditions and the incidence and severity of diseases and pests (Denton and Fajemisin, 1976). From rainfall and solar radiation data obtained over five years at Nsukka (Ezedinma, 1976) it is apparent that the best period for planting rainfed maize in Nsukka area is about mid-April. Although the magnitude of the reduction in yield that may be incurred by planting maize outside this optimum period has not been reported in literature for Nsukka area, results from other areas suggest that the reductions in yield can be substantial. For instance, maize plant-

ing delayed one, two and three weeks after the optimum period (May 7-12) in Ohio resulted in reductions of about 8, 28 and 56% of the average yield for the area (Leonard and Martin, 1963). At the International Institute of Tropical Agriculture, Ibadan, it was found that maize yields from April planting were about double those from May planting (IITA, 1971). Maize planted in April resulted in a yield of 4 600 kg/ha while maize planted in May yielded only 2 310 kg/ha.

From the above considerations, a one week critical period (around mid-April) for completing seedbed preparation and maize planting was assumed for Okpuje. This is equivalent to 60 h on the assumption of 10 h of work each day of a six-day work week. Thus for optimum yield of maize at Okpuje, ridging and planting operations must be completed in 60 h. This time is shared between the two operations as follows:

$$T_r = \frac{Rp(ha/h) \times 60h}{Rr(ha/h) + Rp(ha/h)}$$

and

$$T_P = \frac{Rr(ha/h) \times 60h}{Rr(ha/h) + Rp(ha/h)}$$

where

Tr = critical time for ridging, h
Tp = critical time for planting, h
Rr = rate of ridging, ha/h
Rp = rate of planting, ha/h

Using values previously determined for rates of operation by hand (Anazodo, 1976) and by tractor (Anazodo, 1982c), the corresponding values of Tr and Tp were calculated from the above expressions. The result is shown in **Table 3**.

Table 3 Rate of Operation and Critical Time of Operation for Ridging and Planting of Maize

Item	Operation	
	Ridging	Planting
Rate of Operation (ha/h)		
Hand-powered	0.002[1)]	0.008[1)]
Tractor-powered	0.56[2)]	0.45[2)]
Critical Time of Operation (h)		
Hand-powered	48	12
Tractor-powered	27	33

1) Source: Anazodo (1976)
2) Source: Anazodo (1982c)

Other rates of operation determined were 0.03 ha/man-day (or 0.003 ha/h) and 0.06 ha/man-day (or 0.006 ha/h) for weeding by hand and harvesting by hand, respectively. Most farmers in the study area weed their maize farm twice in each cropping season, although maize is usually intercropped with cassava and one or two vegetable crops.

The cost of labour used in all manual operations was ₦5.00/man-day or ₦0.50/h.

Determination of Optimum Size of Farm

A graphical approach was developed and used in determining the optimum size of farm a farmer can cultivate effectively if he is to complete the essential field operations timely. The procedure for determining the optimum size using the time curve, cost curve and critical time required for accomplishing the operation is illustrated in **Figs. 1** and 2. The curves given are for hand-ridging and tractor-powered disc ridging operations. Similar curves were plotted for maize planting by hand; maize planting with a tractor-powered planter; twice weeding by hand and maize harvesting by hand. It was felt that maize combine harvesters are too large for use in small farms. The values derived from the graphical analysis are shown in **Table 4**. The optimum size for the hand-powered system was determined as 0.095 ha. On the other hand, the optimum size for the selectively mechanized system was determined as 16 ha. The table reveals that the total cost for the hand-powered operations were lower than those for the tractor-operated operations. More importantly, the cost per hectare for performing tractorized operations was much lower than those for performing the same operations by the traditional hand-hoe method.

Economic Justification of Selectively Mechanized System

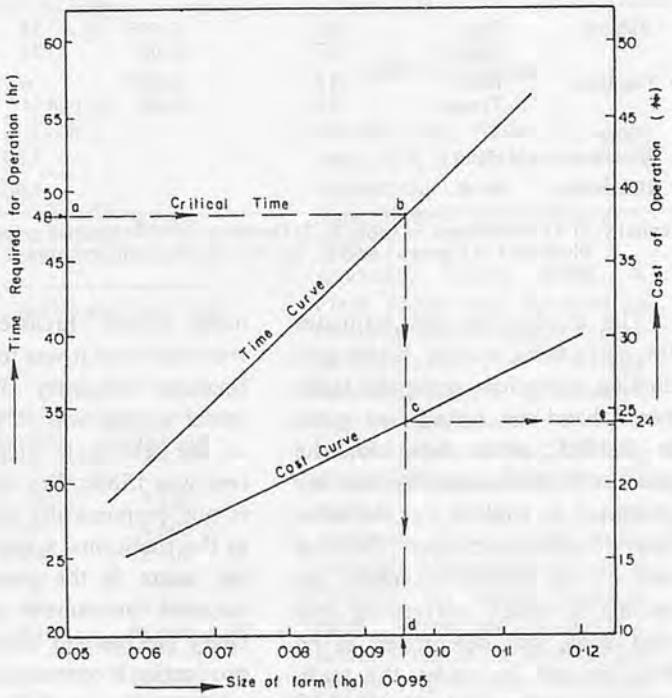


Fig. 1 Determination of optimum size and cost of ridging using a hand hoe.

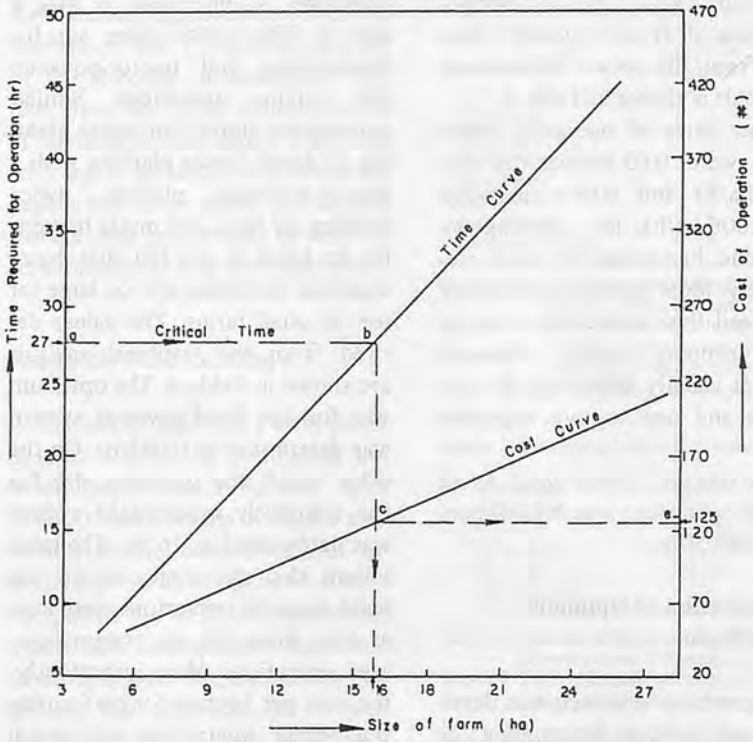


Fig. 2 Determination of optimum size and cost of ridging using tractorized equipment (a disk ridger).

Table 4 Determination of Optimum Size of Farm and Cost of Operation for Selected Hand-powered and Tractor-powered Field Operations for Maize Production at Okpuje

Operation	Power system	Critical time requirement[1]	Optimum size[2]	Cost of operation[3]	
		hr	ha	₦	₦/ha
Ridging	Hand	48	0.095	24	252.63
	Tractor	27	16.00	125	7.81
Planting	Hand	12	0.095	6	63.16
	Tractor	33	16.00	154	9.63
Twice Weeding	Hand	–	–	7.90	83.33
Harvesting	Hand	–	–	7.90	83.33

Remarks: 1) As determined in Table 3; 2) Optimum size determined graphically as illustrated in Figures 1 and 2; 3) Cost of operation determined from Fig. 1 and 2.

The production cost estimates for performing various maize production operations using the traditional hand-hoe system are given in **Table 5**; while those for the selectively mechanized system are presented in **Table 6**. For the same rates of agronomic inputs, the total cost of the production inputs, including the cost of performing field operations, was determined to be ₦637.66 per ha under the traditional hoe system; but only ₦342.10 per ha under the selectively mechanized system. Break-even analysis was made and it was found that the financial efficiency of the traditional system was 85% while that of the selectively mechanized system was 158%. This implies that it is not economically wise to invest in the traditional system of producing maize in the project area. In contrast, investment in the selectively mechanized system of maize production is economically justified.

Equipment Selection

Calculations as detailed elsewhere (Obiji, 1983) lead to the recommendations made on **Tables 7** and 8 for maize production as a sole crop on 252 ha available at the Okpuje Farm Project. The recommendations are only instructive since it is unlikely that the entire area of the farm project will be devoted to continuous maize production. The set of equipment recommended are: three disc ploughs; two disc harrows; three disc ridgers, three rotary cultivators, three maize planters and three medium four-wheel tractors. The sizes of the equipments are given in **Table 7** while the operating cost and the recommended percentage subsidies are given in **Table 8**. The total capital required for the purchase of the set of equipment recommended was determined as ₦74 200 (at current prices of the equipment from local dealers). With this sort of analysis a more systematic recommendation and estimation of the type, size, number and capital requirement for selectively mechanizing rural farm project can be made. The analysis will also facilitate the design and implementation of systems for the rural agro-service centres being established by the Federal Government of Nigeria.

Conclusions

The introduction and use of mechanized equipment into the Nigerian agriculture have always been considered to be ineffective and expensive for the small farmer. This misconception has persisted because of the general approach to agricultural mechanization which fails to take into consideration the selective nature of agricultural mechanization and its comparative economic advantages over the traditional hand-hoe system. Agricultural mechanization should be considered simply as an input-factor into the production function of a

Table 5 Production Cost Estimation for Traditional Hand System (Maize)

Item	Price ₦/kg	Input kg/ha	Output kg/ha	Input ₦/ha	Output ₦/ha
Maize Seed	0.50	6	1 077.5	3.00	538.75
Fertilizer	0.20	100	–	20.00	–
Labour: Ridging	–	–	–	250.00	–
Planting	–	–	–	63.00	–
Twice Weeding	–	–	–	83.33	–
Harvesting	–	–	–	83.33	–
Shelling	–	–	–	85.00	–
Land Charge	–	–	–	50.00	–
Total	–	–	1 077.5	637.66	538.75
Rreakeven yield	=	$\frac{637.66}{0.50}$	=	1 275.32	kg/ha
Breakeven price	=	$\frac{637.66}{1\,077.5}$	=	0.59	N/kg
Financial efficiency	=	$\frac{538.75}{637.66} \times 100\%$	=	84.49%	

Note: (1) When the financial efficiency is less than 100% it is not economical to invest on the project. (2) Calculations based on rates determined by Anazodo (1976; 1982c) and Ibe (1982).

Table 6 Production Cost Estimation for Selective Mechanization of Maize[1)]

Item	Price ₦/kg	Input kg/ha	Output kg/ha	Input ₦/ha	Output ₦/ha
Maize Seed	0.50	6	1 077.5	3.00	538.75
Fertilizer	0.20	100	–	20.00	–
Machinery operations	–	–	–	17.44	–
Twice weeding by hand	–	–	–	83.33	–
Manual harvesting	–	–	–	83.33	–
Shelling (Manual)	–	–	–	85.00	–
Land charge	–	–	–	50.00	–
Total	–	–	1 077.5	342.10	538.75
Breakeven yield	=	$\frac{\text{Total input costs}}{\text{Price}}$	=	$\frac{342.10}{0.50}$	
	=	684.20 kg/ha			
Breakeven price	=	$\frac{\text{Total costs}}{\text{Expected yield}}$	=	$\frac{342.10}{1\,077.5}$	
	=	0.32 H/kg			
Financial efficiency	=	$\frac{\text{Output}}{\text{Input}} \times 100\%$	=	$\frac{538.75}{342.10} \times 100\%$	
	=	157.48%			

1) Calculations based on rates determined by Anazodo (1976; 1982c) and Ibe (1982).

Table 7 Equipment Recommended for Okpuje 252 ha Maize Production Project[(1)]

Equipment	Number	Size	Unit price ₦/unit	Initial cost ₦
Plough (disc)	3	1.8 m	2 500	7 500
Harrow (disc)	2	3.2 m	2 300	4 600
Ridger (disc)	3	2.0 m	2 800	8 400
Rotary cultivator	3	3.0 m	2 600	7 800
Planter	3	3.5 m	3 300	9 900
Tractor	3	32kW[(2)]	12 000	36 000
Total	–	–	–	74 200

Remarks: (1) Detailed calculations were made by Obiji (1983).
(2) Calculated tractor drawbar power (32 kW = 41 hp).

Table 8 Estimated Operating Costs and Recommended Government Subsidy

Operation	Operating[(1)] cost ₦/h	Subsidy[(2)] (%)
Ploughing	9.28	44
Harrowing	8.54	47
Ridging	9.59	49
Rotary cultivating	8.79	36
Planting	8.75	47

Remarks: (1) Detailed calculations were made by Obiji (1983). (2) Subsidy in five states: – Imo, Rivers, Kaduna, Ogun and Bendel (Anazodo, 1982c).

given agricultural enterprise. It can, therefore, be accepted or rejected only after a careful quantitative economic evaluation.

For the selected project area, it has been demonstrated that the selectively mechanized system of maize production is economically justified while it is unwise to continue to invest in the traditional hand-hoe system for the production of maize. It is also clearly shown in this paper that selective mechanization offers the small farmer an oppoutunity to increase the total area he can effectively cultivate annually and, consequently, to increase his income.

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Need for National Cooperative Tillage Research in Pakistan



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Abstract

A proposed project entitled 'National Cooperative Tillage Research' for Pakistan is outlined. The lack of appropriate tillage implements and planting equipment has been identified as two of the major constraints to further increase in per hectare crop yield in Pakistan. The need for immediate action in research, training requirements and local design and development of seedbed preparation and planting equipment, is stressed.

Introduction

The utilization of improved seeds, irrigation facilities and biochemical inputs have helped towards increased crop production. Since this 'green revolution' in Pakistan in the 1970's the crop yield has been once again increasing.

In recent years the introduction of mechanical harvesting and threshing machines have helped to collect the products with minimum field losses. Statistical data over 10 years (1970-80) show that, despite large investments in various farm inputs, an overall increase of only 0.6 t/ha of wheat was achieved over this period. A further analysis shows that a 0.24 t/ha increase was achieved by bringing extra (perhaps more fertile) land into production. The remaining 0.35 t/ha increase was attributed to biological and mechanical inputs.

The statistical data also show that most other crops (except perhaps rice which had shown a modest increase) registered little or no increase in yield. Hence, a large gap still exists between present and potential yields.

Published data have clearly associated low yield/ha with the outdated methods and equipment used for seedbed preparation and for sowing methods (Chaudhry *et al,* 1982; Sheikh *et al,* 1983). A recent report (Choudhary, 1982) has also identified angro-climates where excessive cultivation is leading to large-scale erosion on one hand, while on the other hand, traditional methods of crop production have been unable to utilize soil resources to their potential, particularly in low rainfall areas.

Present Tillage Practices and Machinery

Present technology for seedbed preparation in Pakistan revolves around the use of a tine-type cultivator traditionally drawn by a pair of bullocks, or more recently by tractors, the numbers of which are rapidly increasing.

There are still millions of hectares of "barani" (rain-fed) areas in Pakistan. Experience suggests that an increase of 20-30% in crop production could be achieved by replacing broadcast methods of sowing seeds with drilling machines that have suitable seed spacing and depth control for better seed germination and plant establishement.

Fetilizer application is normally done conveniently by surface broadcasting. This method has been shown to be least efficient in terms of nutrient availability to plants. For example, in Pakistan the fertilizer field efficiency is estimated to be only about 14%. Research and experience from other countries (for example from India, which has comparable agroclimates to that of Pakistan) suggests that field increases of 20-25% in crop production were possible by placing the fertilizer close to the seed microenvironment. Nitrogenous fertilizers such as urea and DAP (which are in common use in Pakistan) are highly volatile, therefore it would be preferable to mix or place them in the soil, instead of broadcasting on the soil surface.

There is only one type of seed

Acknowledgements: This paper has been partly extracted from a report submitted to the Pakistan Agricultural Research Council (PARC). The report was written as a result of the auther's second visit to the PARC under the United Nations Development Programme's 'TOKTEN' scheme in November 1983.

drill being manufactured in Pakistan. The use of such drills is limited because these are obsolete and almost uneconomic to use except in very favourable growing conditions. A few imported drills are available at some agricultural research establishments. However, despite their potential advantages, these drills are not popular amoung farmers because they are expensive, complicated and of a trailed type, therefore, difficult to operate by inexperienced and mostly uneducated operators.

It has been estimated (Friesen and Korwar, 1983) that overall losses caused by weeds are about 27% for both rain-fed and irrigated areas. Presence of weeds reduces crop yields by competing for moisture and nutrients, etc. The use of herbicides, mechanical weed control, and suitable crop rotations can help to minimize losses due to weeeds. It has also been suggested (Rahman, pers. com. Barani Agricultural Research and Development, Pakistan) that up to 50% increase in crop production per unit area was possible in the rain-fed areas of Pakistan by properly exploiting the soil and water resources with the use of an appropriate tillage and seed sowing technology.

In view of the above mentioned problems associated with the present status of tillage, and the potential to improve yields, it was highly desirable that research efforts were coordinated and consolidated to use national resources most responsibly and in a more productive manner.

National Cooperative Tillage Research Programme

As a result of the author's visit in November 1983 to the Pakistan Agiricultural Research Council at the latter's invitation, a project report was compiled. It was proposed that as a matter of urgency a 'National Cooperative Tillage Research Programme' be initiated to define 'optimum' tillage and equipment requirements for maximum crop production in Pakistan.

The specific aims of this project proposal were to:

1. Analyze an inventory of tillage and seed drilling equipment resources and constraints in Pakistan in order to establish the priority of a 'National Cooperative Tillage Research Programme'.
2. Select, modify and develop prototype tillage and planting equipment to resolve identified angro-economic tillage constraints.
3. Test tillage/planting equipment under selected cropping patterns to determine their economic acceptability in view of energy and power use efficiency.
4. Develop and/or transfer technology aimed to accelerate adoption of improved tillage/planting practices.
5. Recommend tillage/planting equipment manufacturing policy in Pakistan.
6. Provide necessary training that will improve the manpower base on which to conduct tillage/planting R and D activities.
7. Lay the foundations of National Tillage Research capabilities for on-going research on tillage in Pakistan.

These project proposals were prepared in the light of the following considerations and constraints:

a. The project shall be nationwide and representative of major eco-climatic zones and cropping patterns.
b. In view of the needs of the country, the project requires speedy approval and implementation. Therefore, the project budget was initially kept within easily affordable limits.
c. Because of the resource limitations the project should be implemented in two phases, i.e., initially 3 years to be followed by another 2-3 years.
d. The project shall utilize existing institutional, workshop and scientific resources as far as possible.

The project proposals also laid down the personnel requirements (both professional and technical), experimental sites, and machinery needs for Pakistan. It was proposed that the National Cooperative Tillage Research Programme be located at the National Agricultural Research Centre (NARC) in Islamabad. The NARC shall provide necessary building facilities and the programme will work in close collaboration with the Farm Machinery Institute. Sub-centres for the programme were proposed to be located in the provinces at those places where some scientific and workshop facilities were available.

In the initial stages of the research programme there will be some gaps in the availability of scientific manpower. To alleviate this problem, training needs and potential training centres have been identified.

Conclusions

Despite large investments in the provision and improvement of seed, fertilizers and irrigation, crop yield is still low in Pakistan. One of the limiting factors which has received little attention is the use of age-old and obsolete methods of cultivation, seedbed preparation and seed sowing equipment.

There is a definite need for coordinated research and development to define and specify the machinery needs and their manufacture in Pakistan. Improved machinery and crop production methods are needed before the gap between the present and potential yields can be narrowed.

(Continued on page 64)

Sunflower Oil:
An Anticipated Diesel Fuel Alternative



by
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Abstract

The physico-chemical properties of sunflower oil and its methyl ester were examined and compared with No. 2 diesel fuel. The fuel performance characteristics of the sunflower oil were investigated by operating a Buda diesel engine.

The kinematic viscosity, cloud, pour, flash and boiling points of sunflower oil and its methyl ester are higher than those of the No. 2 diesel. The cetane rating and calorific value were lower when compared to the disel (base) fuel. Over 1 h interval, the sunflower oil maintained almost the same power output and thermal efficiency as the No. 2 diesel fuel but the specific fuel consumption was about 6% higher than the reference fuel. About 14 times higher viscosity and low volatility of the sunflower oil do not favour its use in unmodified diesel engines.

Introduction

Concern for the depletion of known petroleum reserves and the rapid escalation of portable energy fuel has caused a renewed focus on the feasibility of using vegetable oils as a substitute fuel for compression ignition engines. On-farm agricultural production in Pakistan consumes less than 1.7%* of the total national energy consumption. However, according to a conservative estimate, this relatively small percentage of energy is worth US$26 million yearly. At this stage the use of vegetable oil in Pakistan as fuel may not be justified because of insufficient local oil production and higher prices. However, knowledge of fuel related properties and preliminary engine testing with some diesel fuel alternative is important in meeting long range energy needs and in gaining independence from fossil fuels. Sunflower oil has chemical and physical properties which give promise to the potential of becoming a substitute for diesel fuel.

The oil content of sunflower seed (40-53%) varies among a large number of varieties grown in widespread geographical regions in accordance with climatic adaptability. The different varieties can be classified on the percentage of oil content which can be identified as (1) an oil type (40-53%) or (2) a non-oil type or confectionery (25%) sunflower variety. Oil type varieties due to their higher oil yields have a more favourable energy output to input ratio which is about 8 to 1 under Pakistani situation.

*Agriculture Statistics of Pakistan, 1981 and Pakistan Engineers, December, 1982.

Chemical Composition of Sunflower Oil

Sunflower oil is similar to other vegetable oils in its chemical composition and is mainly composed of triglycerides (approx. 95%) and non-triglycerides (about 5%). Triglycerides are esters composed of one molecule of glycerol and three molecules of fatty acids (Formo et al, 1979). A molecule of triglycerides contain 94 to 96% fatty acids by mass. Therefore, these acids predominantly affect the physico-chemical properties (e.g. viscosity, density, calorific value) of an oil.

It is interesting to know that the proportions of saturated and unsaturated fatty acids vary with climatic region of the globe. In the colder regions the linoleic acid (unsaturated) is about 75%. But in

tropical regions this changes to about 50% whereas oleic acid (saturated) increases to about 35%. The latter proportions favour the lower viscosity and density. The free fatty acids (about 0.5%) are crucial for the flash point of a vegetable oil.

The hydrocarbons, waxes and sterols (non-triglycerides) affect the cloud and pour points whereas the tocopherols, as antioxident (non-triglyceride) determine the oxidation stability of a vegetable oil (Formo et al, 1979).

Methodology

The fuel-related properties of crude-degummed sunflower oil and its methyl ester were determined by using the ASTM (American Society of Testing and Materials) test procedures specified for diesel fuel. These are kinematic viscosity, pour, cloud and flash points, distillation curve, calorific value and API (American Petroleum Institute) gravity. Some other fuel related properties which could not be determined by the author due to lack of proper equipment were found by the Alberta Research Council (ARC), Canada. Results at the ARC about cetane number, oxidation stability and carbon residues are reported in the results and discussion section. The methyl ester of sunflower oil was prepared by esterification of sunflower oil in the department of chemistry, University of Manitoba, Canada.

A bench test was conducted to investigate the effects of sunflower oil on a typical diesel fuel system. Engine performance characteristics were found by operating a Buda diesel engine.

Results and Discussion

Kinematic Viscosity

The viscosity of liquids is a function of temperature. Kinematic viscosity affects the performance of the injection system. Low viscosity can result in excessive wear in the injection pumps and power loss due to pump and injection leakage. Higher viscosity may result in excessive pump resistance, filter blockage, high line pressure and coarse atomization. The kinematic viscosities of sunflower oil and its methyl ester are compared with diesel in **Fig. 1**. At 37.78°C, sunflower oil was 14 times more viscous than diesel fuel. The viscosity of methyl ester was about twice that of diesel. At temperature lower than 30°C the viscosity of sunflower changes more drastically (about 24 times more viscous than diesel at 0.0°C) and makes a steeper curve whereas the viscosity curve of the methyl ester remains fairly close to diesel fuel. It can be conceived from **Fig. 1** that the higher viscosity of sunflower oil, in cold climates, will appreciably affect the fuel system operation.

Cloud and Pour Points

These two fuel properties are important in predicting the temperature at which the fuel is sufficiently fluid to be pumped or transferred. The cloud point is the temperature at which a cloud or haze of wax crystals appears at the bottom of a test jar when chilled under prescribed conditions. The pour point is defined as the temperature at which movement of the oil is last

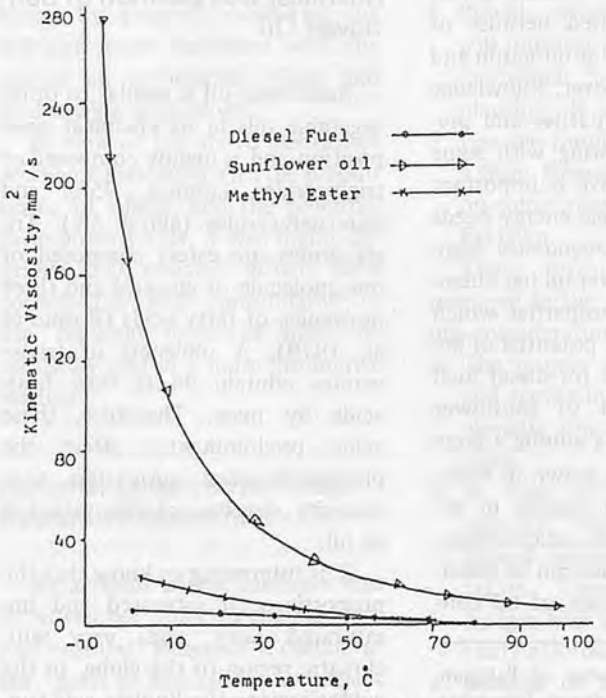


Fig. 1 Kinematic viscosity of No. 2 diesel fuel, crude-degummed sunflower oil and its methyl ester.

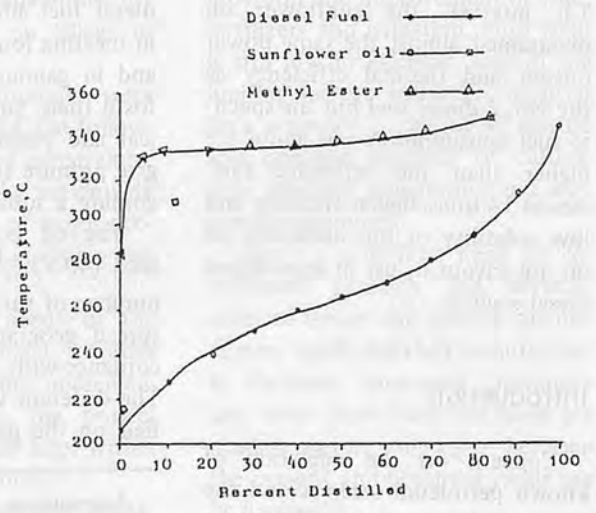


Fig. 2 Distillation curves of No. 2 diesel fuel, crude-degummed sunflower oil and its methyl ester.

observed. Both of these properties may indicate a tendency towards filter plugging and flow problem in fuel lines. The cloud and pour points, 7.77°C and 15°C, respectively, observed for sunflower oil are a little higher than No. 2 diesel fuel as 9.0°C and 18.5°C, respectively. However, the cloud and pour points, 2.8°C and 4.0°C, respectively, of the methyl ester vary to a greater degree when compared to No. 2 diesel. The difference in the results may be attributed to the degree of refinement of the oil.

Flash Point

The flash point indicates the minimum temperature at which the vapors of the fuel can catch fire but cannot support flame. This parameter is important in handling and storing of a fuel. The observed flash points of sunflower oil and No. 2 diesel were 214°C and 68°C, respectively. This greater difference can be attributed to the longer carbon chain (57) and the degree of unsaturation (3 to 6 double bonds) in the case of sunflower oil.

Boiling Point and Distillation Curve

The boiling point indicates the temperature at which fuel starts vaporizing. Distillation curve is important for starting of an engine. Higher boiling point reflects the presence of engine starting troubles. The distillation curves of No. 2 diesel fuel, methyl ester and the first two points of the sunflower oil curve are shown in **Fig. 2**. At 214°C the initial boiling point of sunflower oil was observed and at about 316°C only 10 m*l* of darkened distillate passed over along with heavy dense white fumes and a very irritating odor. The preceding situation of the oil represents the chemical decomposition of the fatty acids. At this premature stage distillation was discontinued. The distillation of the methyl ester was statisfactory up to 85% recovery of the sample after which thermal cracking took place. It is important to note that engine starting problem will be greater for oil produced in cold climates where a higher ratio of unsaturated to saturated fatty acids exist.

Calorific Value

The calorific value of a fuel is an important property for comparing energy alternatives. The gross calorific value is the heat released by the unit mass of fuel with all the water vapors condensed to liquid state. This property enables the engine to perform useful work. The gross calorific value as presented in **Table 1** for sunflower oil (39.64 MJ/kg) is about 87% of No. 2 diesel (45.67 MJ/kg). The methyl ester (40 MJ/kg) has about 12% less heat content than diesel fuel. Lower heat content of oil and its methyl ester will result into a higher fuel consumption than diesel fuel for the same output power.

API Gravity

This is an index of the fuel density or mass per unit volume. The relationship between the API gravity scale and the specific gravity is

$$\text{API gravity (degrees)} = \frac{141.5}{\text{Specific gravity at } 15.6^\circ\text{C}} - 131.5$$

The API gravity is determined by a hydrometer. In general, high API gravity implies high cetane number for the fuel (Lillijedhal et al, 1979). Since the laboratory was not equipped with a constant temperature bath, a graphical procedure was adopted to determine the API gravity of the fuel at the reference temperature of 15.6°C. The best fit lines with correlation factor of 0.999 were drawn for hydrometer readings of different temperatures. The results of API gravity and density are contained in **Table 2**.

Table 1 Gross Calorific Value of Diesel Fuel, Sunflower Oil and its Methyl Ester

Fueld Type	MJ/kg	MJ/*l*
No. 2 diesel	45.676	38.779
Crude-degummed sunflower oil	39.646	36.633
Methyl ester	40.0	35.17

Table 2 API Gravity and Density of Diesel Fuel, Sunflower Oil and its Methyl Ester at 15.56°C

Fuel Type	API Gravity (degrees)	Density kg/*l*
No.2 diesel	35.13	0.849
Crude-degummed sunflower oil	21.65	0.924
Methyl ester	30.58	0.873

With respect to density, sunflower oil and its methyl ester are about 8% and 3.5% heavier than No. 2 diesel fuel. The lower API gravity for the sunflower oil and its methyl ester reflect poor ignition qualities.

Ignition Quality

The ignition quality of the fuel affects engine performance, cold starting, warm up, combustion roughness, etc. (Lillijedhal et al, 1979). The cetane rating is a measure of the self-ignition quality of the fuel and is the inverse of the octane rating in spark ignition engines. Cetane number is the percentage by volume of normal cetane in a blend with hypatha methyl nonane required to match the ignition quality of the test fuel. The cetane number of sunflower oil is 34 compared with 48 for No. 2 diesel fuel. The difference in the cetane rating is due to less vaporization which is caused by long chain fatty acids.

Carbon Residue

Since sunflower oil is mostly composed of carbon and hydrogen and has a tendency to form carbon deposits when burnt in an engine. If the carbon residue of a fuel is

known then it is easy to predict the carbon deposition from the fuel. The carbon residue determined by ARC is 0.39% for sunflower oil, compared to 0.35% for No. 2 diesel fuel. From the results it may be concluded that sunflower oil will leave more carbon deposits than diesel fuel after burning in the engine.

Oxidation Stability

The oxidation of unsaturated fatty acids increases the viscosity and deteriorates the flavour of vegetable oils with the passage of time (Cobia and Zimmer 1978). In the long run, sunflower oil due to oxidation, tends to leave heavy gum and wax deposits on stationary metal components and fuel tanks. The oxidation stability determined by an accelerated method is 78.3 mg/100 m*l* which is lower than rape seed oil (86.8 mg/100 m*l*) but higher than canola oil (43.6 mg/100 m*l*.)

Engine Performance with Sunflower Oil

The effects of sunflower oil on a typical diesel fuel system were examined by operating a close circuit system (test bench). In the case of sunflower oil, a pressure build up of about 200 kPa was noted in the higher pressure fuel line throughout the testing period of 210 h. This higher pressure can be attributed to the higher density of sunflower oil. Fuel filters plugging resulted from higher viscosity of this oil was also observed by a vacuum gage.

Some engine performance characteristics with sunflower oil and No. 2 diesel fuel were determined by operating a Buda diesel engine. The results of power output vs engine speed are shown in **Fig. 3**. The difference in power output with both the fuels, over a test of 1 h is negligible. **Fig. 4** shows that

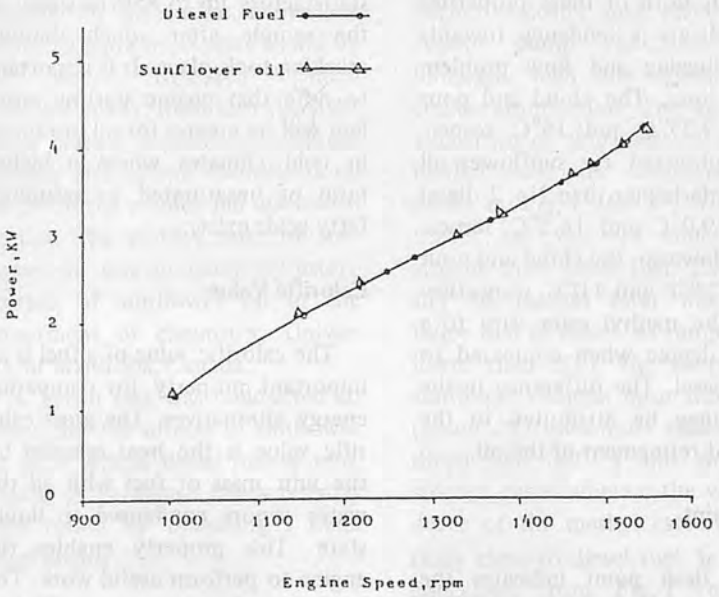


Fig. 3 Power performance curve of No. 2 diesel fuel and crude-degummed sunflower oil.

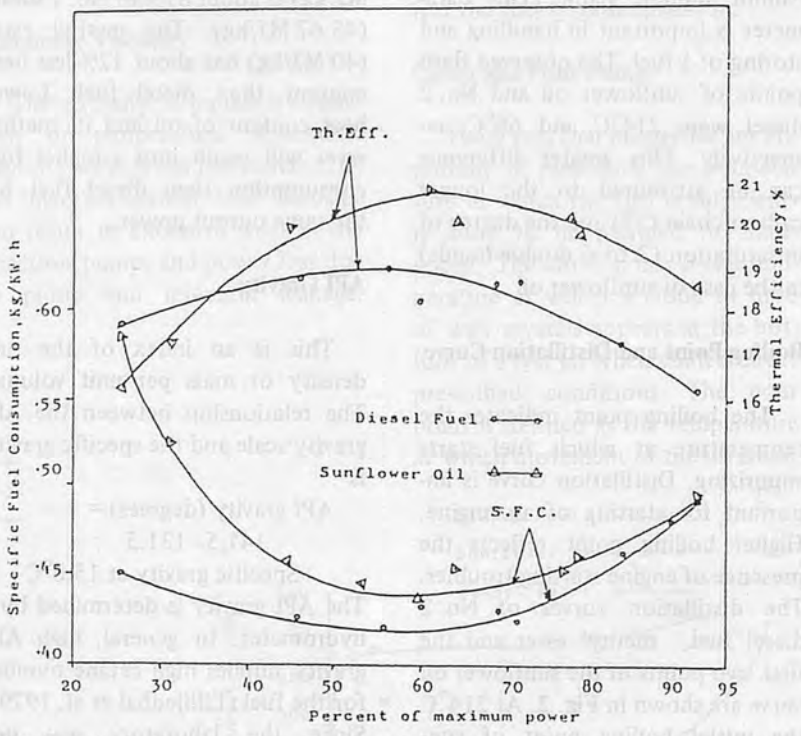
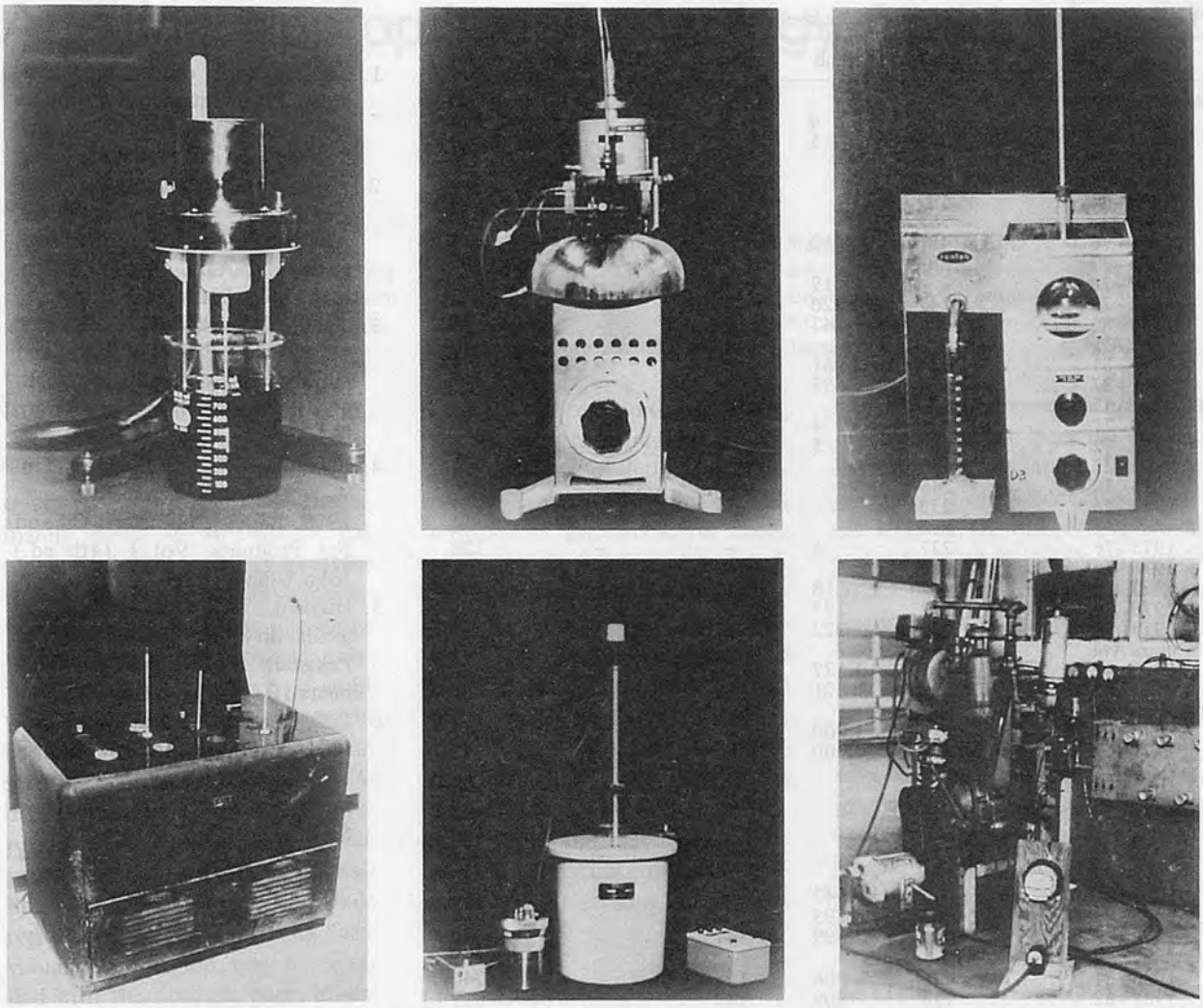


Fig. 4 Specific fuel consumption and thermal efficiency of No. 2 diesel fuel and crude-degummed sunflower oil.

at about 60% of maximum power the specific fuel consumption and thermal efficiency with sunflower oil are 6% and 2%, respectively, higher than No. 2 diesel fuel. The higher specific fuel consumption in the case of sunflower oil is due to its lower energy content, about 13% less than No. 2 diesel fuel. It was also observed that sunflower oil could not flow through the secondary filter, even at room temperature without the introduction of fuel transfer pump in the fuel system. Engine starting problems and heavy knocking were also en-



Apparatus used (top left to right): 1– Viscometer; 2– Flash point tester; 3– ASTM Distillation apparatus; 4– Apparatus for cloud and pour points; 5– Oxygen-bomb calorimeter; 6– Diesel engine for fuel performance test.

countered.

Conclusions

1. The most discouraging property in the use of sunflower oil as fuel is its high viscosity; about 14 times higher than diesel at reference temperature. The problems to be encountered with higher viscosity are filter and fuel line blockage, higher injection pressure and poor atomization.
2. The problem of higher viscosity may be solved by transesterification of sunflower oil to methyl ester. Its pour point limits its use in tropical climates provided its economy of utilization can be justified.
3. The cetane rating and volatility are related to the knock characteristics and ease of cold starting. Sunflower oil has relatively low cetane rating and high boiling point. The alternate fuel was not able to start a cold engine as readily as No. 2 diesel.
4. The calorific value of sunflower oil is about 13% less than No. 2 diesel fuel. Since the fuel consumption is not totally dependent on the difference in heat values, only 6% more sunflower oil consumption was recorded.
5. The thermal efficiency of sunflower oil is quite satisfactory in an engine with an indirect combustion system. It means the contamination of the lubricating oil may be delayed.
6. Oxidation of vegetable oils is also a limiting factor in their storage and utilization as fuel. Higher oxidation rates will leave heavy gum and wax deposits in engine fuel tanks and on stationary engine parts when exposed to high temperatures and free oxygen.
7. Sulfur content, carbon residue and ash content of crude-degummed sunflower oil are quite comparable to diesel fuel. Due to lower sulfur and ash content less corrosion and abrasion is expected.

Table 3 Planted Area, Production and Yield of Sunflower, Pakistan

Year	Punjab	Sind	N.W.F.P.	Baluchistan	Total
Area in ha					
1970–71 ..	666	4	–	–	670
1971–72 ..	1 245	5	–	–	1 250
1972–73 ..	769	–	7	–	776
1973–74 ..	516	–	–	–	516
1974–75 ..	569	–	–	–	569
5 years Avg . . .	753	–	–	–	756
1975–76 ..	481	2	–	–	483
1976–77 ..	389	–	–	–	389
1977–78 ..	–	19	18	–	37
1978–79 ..	247	220	12	–	479
1979–80 ..	267	247	78	–	592
5 years Avg.	–	–	–	–	396
1980–81 ..	2 634	1 961	84	–	4 679
1981–82 ..	3 514	3 655	66	–	7 235
Production in t					
1970–71 ..	478	4	10	–	482
1971–72 ..	868	5	–	–	873
1972–73 ..	483	–	3	–	486
1973–74 ..	246	–	–	–	246
1974–75 ..	259	–	–	–	259
5 years Avg.	467	–	–	–	469
1975–76 ..	227	1	–	–	228
1976–77 ..	188	–	–	–	188
1977–78 ..	–	18	17	–	35
1978–79 ..	112	197	2	–	311
1979–80 ..	122	222	11	–	355
5 years Avg.	–	–	–	–	223
1980–81 ..	1 701	1 177	14	–	3 492
1981–82 ..	2 522	3 321	12	–	5 855
Yield in kg/ha					
1970–71 ..	718	1 000	–	–	719
1971–72 ..	694	1 000	–	–	698
1972–73 ..	628	–	428	–	626
1973–74 ..	477	–	–	–	477
1974–75 ..	455	–	–	–	455
5 years Avg.	620	–	–	–	620
1975–76 ..	472	–	–	–	472
1976–77 ..	483	–	–	–	483
1977–78 ..	–	947	944	–	946
1978–79 ..	453	895	187	–	649
1979–80 ..	457	899	141	–	600
5 years Avg. –		–	–	–	563
1980–81 ..	646	906	167	–	746
1981–82 ..	718	909	182	–	809

Source: Agricultural Statistics of Pakistan, 1982.

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(Continued from page 58)

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Auditing Appropriate Technology Appropriately

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Introduction

Appropriate technology, in order to be sufficiently and ultimately useful in all respects, has to be truthfully tested at all stages from conception to implementation. The preliminary questions together with the positive solutions constitute an array of audit which is necessary for a meaningful technology. The auditing itself consists of two important bases – individual and national. An appropriate technology has to be appropriate not only to the individuals but simultaneously to the whole region comprising them. An individual, like a region, may be classified into the poorest, poor, lower-middle, upper-middle, rich and richest. It is to be tested as to which class benefits most by the said technology, keeping in mind that poor does not become poorer nor stands static, while rich may become richer. A socially and politically tolerable gulf among different classes could be the better choice, depending upon the geographic and historical sensitivities.

Auditing

An audit for appropriate technology should, therefore, take into account the following variables:

Social-audit

This includes social customs, society-taboo, superstitions, status-requirements, traditions, prejudices, family and regional traditions.

An example of status-conscious society is, burning wood/coal as compared to gas/electric for cooking. While the former is low standard, the latter belongs to a high-status symbol. Another social practice in some rural areas is to go to the fields for sanitary habits and no formal lavatory is required. There is no question, therefore, in introducing technology regarding sanitation problems. A solar cooker to be used during the day may not be useful for the rural folks who have a tradition of cooking in the cool evenings.

Cultural-audit

This pertains to cultural practices and religion. In most of the underdeveloped areas of the world, and especially rural areas, women have been neglected for ages so far as development of the helping and labour saving devices is concerned. The dominance of men over women, sometimes, has the effect that men even do not know the available technology for the benefit of women labour force in agriculture and agro-industry. One of the cures may be to include women in training programmes of all available appropriate technologies.

Religion controls the slaughtering mechanisms and processing of animals, and water heating facilities for human beings. Only slow rather than quick killing of animals is permitted under ISLAMIC Law.

Individual -requirement -audit

This includes personal tastes, likings, emotions, ambitions, pride and interest are a part of such audit. In India, Gandhi (1) maintained years back that handloom would teach masses the dignity of labour, foster pride and self- reliance.

Economic and Financial - audit

Economy or cost to individuals and regions, availability and utilization of local labour and manpower, employment, financial considerations both at input and at output stages, initial investments and economy of production are some of the problems needing solution. For example, biogas scheme had flopped (2) in South West part of India because individual plants were very expensive and only well-off farmers could afford them.

Political -audit

This includes personal, local and regional ambitions, government taxes, tariffs and duties; and government/national policies and laws.

As an example, the Indian handicraft laws in the past would not allow polyster fibre (taxed very heavily) to be treated at par with indigenous cotton, silk and woolen which were completely exempt from taxes even as polyster fibre was produced locally from Indian petroleum refined in Indian refineries. The issue had been based more on emotion and Gandhian ambitions of self-reliance.

Time -audit

Considered under time-audit are short-term, long-term prospects and aspects affecting a pre-determined number of generations.

Environmental -audit

The technology has to meet the minimum of prescribed standards of environment, i.e., maintenance and/or least disruption of the environment, ecological balance and non-pollution are the urgent considerations. Environments also affect the technology. Splinter (3) maintains that the impact of mechanization on agriculture could be greater in the tropics than in temperate climates because human and animals would be limited in the level of physical labour they could perform in the humid tropics.

Resource -utilization -audit

The technology should utilize the existing resources, or if not available, the most economical import should be planned. Local resources like agriculture, forestry, minerals, land and water are the starting steps and are to be explored and associated with the technology.

Defensive-audit

Defence to individual and region with respect to safety of life, health, exploitation of manual and mental capabilities, and other undesirable elements should be built into the technology.

Self -sufficiency -audit

The technology might have the tendency to make individuals and regions to be dependent on either technology itself or on the donor agency like individuals, organizations and nations. Not only this has to be checked but the technology should be such as to promote self-sufficient capabilities of all concerned.

Planning -audit

This includes proper planning and avoidance of misplanning, priority concepts and systematic approaches and manipulations. As an example of rural people, burning wood for cooking has been practised for ages, and yet no efficient wood burning stove of the order of 30 to 50% efficiency is available. It is only 5 to 10% heat that is obtained by burning wood in the open and the rest goes to waste. Similarly, a design may be efficient and better for designer but is not so when used by the rural consumer as compared to the urban counterpart. Tran and Saxena (4) emphasize that in considering the utilization of alternative sources of energy in rural areas, it would be important to determine the energy requirements and the appropriate technology which could be utilized to fit socio-economic aspects.

Audit at the Transfer level of appropriate technology is based on two foundations: i) the shaping up of appropriate technology from advanced and/or available appropriate technology and ii) the receiving-end or end-user.

This can be split further into international level (for example from one country to another) and national level where urban to rural, organizations to individuals, individual to individual are meant for all round development.

Auditing also involves two important factors for appropriate transfer of technology: i) transfer is done in the spirit of mutual and not one way interest and ii) it does not drastically affect the lives of the people of the receiving regions. For a better transfer of an appropriate technology, human values are mixed with technological values wherein the former exercise authority and control over the latter in order to prevent technology getting out of control. There has to be a balance between technological and human values, and a guidance and assigning of meaning to the technology is possible by human beings.

There are some more questions to be settled for a proper audit like: i) what determines what?, or in other words, the third world's environment determines the technology or vice-versa; ii) is it desirable to develop and transfer from outside to inside or only inside to inside; iii) is it possible to have the motto of audit to see ultimately how the technology works, how locally available and understood materials are utilized, and how it operates through sources of energy which are locally and cheaply available like wind, water, solar, animals and human beings.

In summary, the Final-Audit assumes: i) how quality of life is improved in terms of food, fibre, clothing, shelter and general living, and ii) how national economy is affected.

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Mechanization of Sugarcane Farming in India



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Introduction

Mechanization, in practice, means performing an operation better and faster. In the context of agricultural operations, it does not mean tractorization. In fact, the title of this paper could also have been 'Modernization of Sugarcane Farming'. All concerned agencies are keen on modernization of the industry and the process is being accelerated. But in the case of agriculture, very few talk of modernization, and in a way, it seems to be confined to the use of high yielding varieties of seeds and application of fertilizers and pesticides.

India occupies a pride of place in the sugarcane world today. With an expected production of 180 million t of sugarcane in 1983-84, India may be the world's largest cane grower. But India's sugar price is not competitive in the international market. Taking a long term view, India must initiate steps now to bring down the cost of production through improving the efficiency of operations, better utilization of capital resources, including equipment and modernizing sugarcane farm practices. Indian agriculture needs to be provided with a better technology base so that it can not only meet the domestic demand but also develop exports of agriculture products on a sustained basis.

With over two decades of mechanization of agriculture, India still seems to be in the first stage of providing better power input and taking care of the basic farm operations of tillage and haulage. It is time we graduate into the second stage of crop specific mechanization, introducing a wide range of equipment for different farm operations, greater utilization of farm prime movers like tractors and stepping up the power input to a level of 1 hp/ha. Primary power sources to Indian agriculture include 66 million bullocks, 600 000 tractors and 7.5 million pump-sets. On a total of about 145 million ha of cultivated area, the power input is about 0.6 hp/ha. World-wide studies conclude that to get an optimum yield, there should be an installed power input of 0.8 hp/ha and in my view this minimum should be raised to 1 hp/ha on sugarcane farms. No data is available on the installed power input on sugarcane farms in India, but overseas it is in the range of 2 to 3 hp/ha. The increase in power input will have to be provided by mechanical means and hence, there is some urgency in accelerating the pace of mechanization of farming operations.

Energy requirements of agriculture must be the subject of an in-depth study and efforts should be initiated to conserve energy to the maximum possible extent. Value of fuels and lubricants annualy consumed on farm prime-movers, primarily tractors and diesel engines, is about Rs. 30 billion. Estimates of high speed diesel oil consumption are 4.5 million t a year for tractors and 2.5 million t for diesel pump-sets, making a total of 7 million t. There is emphasis on fuel efficient engines for motor cars, but the 12 makes of tractors indigenously manufactured are not fitted with fuel efficient engines. Inspite of the large volume of business for fuels and lubricants emanating from the farm sector, as compared to the urban customer, the rural buyer is not getting the type of services expected from the nationalized oil companies in a predominantly agricultural country. Tractor use can be more efficient by promoting better maintenance practices, including regular servicing of tractors and other equipments.

Sugarcane Farm Operations

A review of the present status in regard to mechanization of sugarcane farm operations is summarised in **Table 1**.

Land preparation seems to be comparatively better covered. Some studies are required to determine

Table 1 Present Status of Mechanization of Farm Operations on Sugarcane

Operation	Mechanization	
	Implements available	Gaps
Land preparation	Plough Harrow Cultivator Rotary cultivator	Sub-soiler Ripper
Planting		Sett treatment Planter Fertilizer application
Irrigation	Lift	Soil testing On farm development
	Sprinkler	Drainage
Inter-culture		High clearance cultivation
Plant protection	Knapsack sprayer	Power sprayer (tractor-mounted)
Harvesting	Knife	Harvester
Loading	Manual	Loader
Hauling	Bullock cart Tractor trailer Truck	Road maintenance
Ratooning		Stubble shaver
Bagasse handling		Baler

the use of rotary cultivation under certain conditions. Since sugarcane farms are not ploughed every year, in certain soil conditions, it is necessary to use sub-soilers/rippers for breaking the hard pan and loosening the soils. Preplanting treatment of sugarcane sets is important to ward off diseases and to ensure a healthy tillering. In view of the limited usage during a year of the equipment for treatment of sets, planting and application of fertilizers, there is a scope for popularising custom services for such operations. Overseas, they now use an automatic cutter planter, where the entire cane is fed into the planter, it is automatically cut into sets and the sets are chemically sprayed before they slide into the planting furrow. Fertilizer is an expensive input and hence, it has to be applied at the right time, in right quantities, and placed accurately in the soil, particularly in relation to the distance in horizontal and vertical planes from the sugarcane sets. For accurate placement and metering of fertilizers, proper equipment needs to be developed and popularised.

Water management on sugarcane farms requires urgent attention. Water requirements of sugarcane crop are high and wherever water is available, it is being liberally applied to the sugarcane crop, even to the detriment of the crop health. On-farm development of irrigated sugarcane is a neglected area. Sugarcane fields must be properly prepared and contour levelled, so that they can efficiently use furrow irrigation water. Though at research stations like Lucknow, Padegaon and Rahuri, lots of useful materials are available on soils, their practical use is not being made in determining adequate irrigation application under varying conditions. Drainage is another neglected area. Wherever there is irrigation, adequate drainage provision must be made. Though there are a few sprinkler irrigation installations on sugarcane farms, their utility and cost-benefit ratio need be studied, so that favourable conditions can be identified for popularising them. Contour maps are rarely available and for scientific irrigation practices, it is important that services for topographical survey and contour mapping, etc are available on a custom-charge basis.

Many manual inter-culture operations are either neglected or improperly carried out. The use of chemicals for checking the growth of weeds is getting popular. For inter-culture operations and application of chemicals, including fertilizers and pesticides, there is need for high clearance equipment which can be used in the field when the sugarcane plant has already grown to a certain height. Sprayers and dusters, including power-operated knapsack sprayers are now available but there is scope for a high- clearance, tractor-mounted sprayer for popular use on a custom charge basis.

Harvesting is manually done with a locally made sugarcane knife. There is some urgency in improving the sugarcane harvesting knives, with better ergonomics. Harvesting output is low, to less than 1 t/h in contrast to an output of 200 t/h of cane with use of power operated sugarcane harvesters. In-depth studies of the economics of transportation of sugarcane by bullock-carts, tractor-trailers and trucks are desirable. All 3 popular hauling methods have complimentary roles and there is need to ensure their efficient utilization. Though of late, bullock carts have been mentioned frequently in the press, but the sugarcane grower is still waiting for a scientifically designed bullock-cart with 3 t payload, better weight payload ratio, stub axles for high clearances, built-in camber for better tyre wear, cat's eye reflectors for night plying and brake for negotiating gradients. Better maintenance of roads in sugarcane belts will reduce cost of vehicle maintenance and repairs.

The situation in regard to hand tools and bullock-drawn equipment is not any better. The farmers generally use old designs deprived of the benefits of new technology. Institutions like the Indian Institute of Sugarcane Research, Lucknow, Agricultural Universities at Ludhiana, Pantnagar and Rahuri, and the

Central Institute of Agricultural Engineering in Bhopal have developed some improved tools and implements, but for several reasons they have yet to reach the farmers. The extension and popularising link is very weak and the time lag between development of a new implement and its popular acceptance by the farmers is depressingly long.

It is unfortunate that the country's leading manufacturers like Kirloskars have virtually pulled out of the agricultural implement scene. Laxmanrao Kirloskar did start his enterprise primarily around a steel-plough, but his successors have shifted to greener industrial pastures. Their main contact with the farming community is now through pump-sets. Kirloskar tractors have had problems and the company has now been merged with Kirloskar Pneumatic. At one time, they were experimenting with a knapsack mounted power-operated reciprocating cutting blade for harvesting sugarcane, but of late nothing much has been heard on this project. Other well known manufacturers like Mahindras, Escorts and the Simpson Group have devoted little attention to the lot of the sugarcane farmer. One reason for the big industry shying away from the farm machinery field is the fact that it has been reserved for the small scale industry sector. The SSI Sector will, however, need lots of support by way of designs, proto-types and development of markets. In the meanwhile, the farmer continues to suffer. In the agriculture scene, not confined to sugarcane, there seems to be little priority in the official policies to provide better technological support to development of agriculture.

Sectoral Performance

The strength of the sugarcane lobby in the cooperative sector in Maharashtra is well-known in the political context. They have yet to seriously apply their minds to improving the sugarcane farming technology. It is to be hoped that cooperative leaders of Maharashtra will really worry about the very foundation of their prosperity, i.e., the growing of sugarcane. The farmers are now getting a better price for the cane.

Logistics

There has been a spate of new engineering colleges in Maharashtra and some of them are being set up in rural areas which seems to be aggravating the problem of unemployment of qualified engineers and their migration to cities. The dire need is in fact to train rural youth into such agro-industrial services which will enable them to find gainful employment in rural areas only. There is some urgency in training farm workers in trades like tractor driving, maintenance and repairs of farm machinery, including tractors, pump-sets, sprayers, bullock carts and bio-gas plants, proper water management practices, including land levelling, irrigation and drainage, proper application of farm chemicals including fertilizers and pesticides. It is time to establish a national institute for training in agro-industrial services.

There is scope for developing custom work for several operations on sugarcane farms. If MSFC were able to run their own farms properly, there would have been excellent focal points for developing such services. The Agro Service Centre Scheme of the Government seems to have resulted in only opening more retail outlets for simple trading of farm inputs.

Communications with the farming community is a serious problem area. Because of their level of education, audio-visual media seem to be the most effective. Only our politicians and the film industry have been able to successfully motivate rural folk. But extension of improved agricultural techniques or family planning measures have made slow inroads. The farmer has lot of exposure to socio-political atmosphere, but there is need to develop effective ways for socio-economic and techno-economic development in the rural areas.

A popular bias against mechanization is because of displacement of labour. Today, in the sugarcane belt, farmers in fact are complaining of labour shortage and high wages. It may, however, be noted that inspite of the unfavourable official policies in the case of tractors and lack of services available, the farmers have gone all out in patronizing the tractor as an essential farm prime-mover. There are now over 600 000 tractors in use on Indian farms and the current market size is 80 000 tractors a year. They should have matching implements and a wide range of equipment to utilize this capital investment more efficiently and effectively.

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Importance of Agriculture in the Oil-Rich Kingdom of Saudi Arabia



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Abstract

At present oil revenues contribute 90% of the Kingdom's total GNP and these oil wells are not expected to last long. Therefore, the Kingdom is striving to diversify the economy base to reduce dependency on oil for national prosperity and government revenues by using the available resources to obtain specific goals according to the established priorities. These goals include a high rate of economic growth, development of human resources, social well-being, and the development of physical and infrastructure necessary for the attainment of these goals. Such a diversification started about a decade ago. The primary production sectors are agriculture, petroleum, and minerals. The major emphasis has been on agriculture to minimize the prevailing cash flow being spent on food imports. With all the emphasis on agriculture, the eventual success faces problems due to limited water supply, poor soils, harsh climatic conditions, and manpower.

Introduction

The Kingdom of Saudi Arabia covers about 4/5 of the Arabian Penninsula having the longest coast line extending some 1760 km along the Red Sea and about 560 km along the Arabian Gulf. The total area of the country is 220 million ha and is thinly populated with a population density of about 4/km², including non-Saudi residents. About 30% of the population are nomads but they are quickly becoming settled land owners.

The Kingdom can be divided into several main zones and characterized by a variety of geographical features including vast deserts, high mountain chains, thick jungles, fertile plains, and deep valleys. The country is characterized with high temperatures, in summer it reaches 50°C, humidity is low but it reaches 95% on the coastal areas. The average annual rainfall varies from region to region but it does not exceed 100mm. The annual rainfall exceeds 300mm in the Asir region (**Fig. 1**). The rainfall follows stormy patterns exceeding the absorbing capacity of the soils and thus causes high rates of runoff. The Kingdom mainly consists of

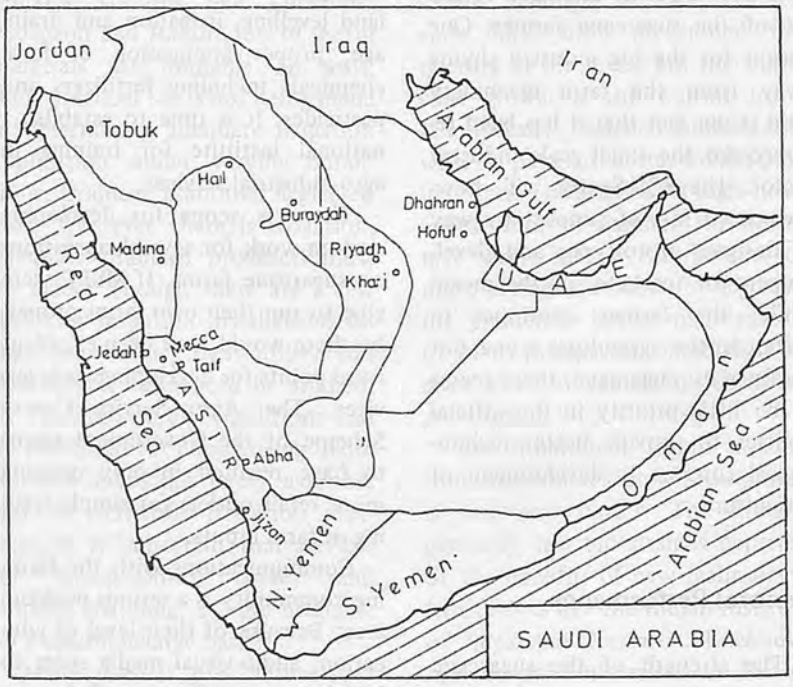


Fig. 1 Map of Saudi Arabia

saline and alkaline desert soils. The limited area useful for agricultural purposes lies in the eastern province and Qasim region generally found in narrow strips nearly flat and level.

Traditionally, agriculture has been practiced around the oases and wadi channels throughout the country where natural springs and shallow groundwaters are available, or where rainfall is sufficient. Some of this land due to excessive agricultural use coupled with poor drainage has lost fertility and become saline. The main source of water for agricultural use is the groundwater, and most of the country is underlain by sedimentary formation, mostly sand, limestone, and shale, and are available as the main sources of groundwater. There are two main aquifers: one is 100-150m deep with limited water supply, and the other is 400-450m deep with unlimited water supply. No river passes through the entire country.

The natives have lived on date and camel and goat meat for centuries but during the middle of this century the Kingdom has emerged as a base for world economy due to huge oil reserves. Presently, oil revenues make up over 90% of the government gross national income. But this oil wealth is expected to dry up within the next 20-25 years. Or, the present global research trend for alternative energy resources will make oil a less important commodity. Therefore, the Kingdom is trying to diversify the source of national economy and reduce dependence on oil for national prosperity and government revenues.

Although the Kingdom has problems due to poor agricultural lands and limited irrigation water, agriculture is the only sector on which she could rely on during any geopolitical crises in the region and or when the oil wells are emptied. The government is well aware of the occurrence of such bad times and, therefore, is trying to mechanize the agriculture at a faster pace. The introduction of agricultural mechanization in developing nations poses several socio-economic problems but the circumstances in the Kingdom are different because of her low population density, high per capita income, willingness to leave old traditions and adopt modern technology, and government's huge spendings on national development programs with special emphasis on agriculture. Of course, the sudden affluency of the region has affected the nomads attitudes toward farming, causing drifting of manpower from the rural areas to the cities and oil producing centers in quest for a better standard of living. And it is somewhat difficult to mold the people's behavior into a system of productive efficiency which bears a long-term effect.

The most challenging problems to agricultural development are. water availability, poor soils, climatic conditions, manpower, improper farming methods, lack of farmer training, lack of extension and research, agricultural cooperatives, and marketing and transportation.

Agricultural Statistics

Of the 220 million ha of total land area, less than 1% falls under the category of agricultural land and only 1/3 of it is irrigated, and the other is rainfed. Of the remaining, 40% is under pasture and forests and the other is all desert. According to recent estimates, per capita of total area is 26.50 ha, whereas per capita of agricultural area is hardly 0.15 ha. Over 60% of the population lives in rural areas. Total economically active population is 29.53% and out of this only 24.24% is assumed to be engaged in agriculture.

Saudi Arabia produces less than half the food it consumes. Sugar, rice, cooking oils, and fats are almost entirely imported. Less than one-half of the consumption of wheat flour, meat, milk, and eggs are produced domestically. **Table 1** indicates how much the Kingdom is lagging behind in agricultural trade balance. Huge deficits in agricultural trade is of course an indication of government spending on heavy agricultural machines and equipment imports. The food trade deficit rise of approximately 20 times over the past decade is partly due to the heavy influx of foreign labor into the country to cope with the on-going giant developmental projects and partly due to poor performance of the agriculture sector.

Imports of all essential agri-

Table 1 Trade Balance of the Kingdom of Saudi Arabia

Unit: US$ million

Year	Total exports	Total imports	Trade balance	Agri. exports	Agri. imports	Agri. trade balance	Food imports	Food exports	Food balance
1970	2 423.82	710.00	1 713.42	4.08	261.05	– 256.97	197.44	2.56	– 194.88
1976	38 283.45	8 693.76	29 589.69	38.37	1 582.40	–1 544.03	912.22	14.83	– 897.39
1978	40 678.77	20 356.61	20 322.16	63.87	3 153.72	–3 089.85	2 100.2	21.64	–2 078.56
1979	63 433.36	24 465.79	38 967.57	48.03	3 127.71	–3 079.68	2 670.24	35.73	–2 634.51
1980	109 083.45	30 165.10	78 918.35	106.97	4 266.18	–4 159.21	3 782.67	74.30	–3 708.37

Notes: 1. Total exports excludes oil exports. 2. Agricultural imports include agricultural machinery, tractors and harvesters. (Source: References 1 and 5).

Table 2 Import of Agricultural Commodities

Year	Quantities of agricultural commodities imported (1 000 t)												Total value (Mill. US$)
	Wheat flour & wheat	Maize	Milled rice	Barley	Cereals	Potatoes roots tubers	Sugar	Pulses	Oilseed, sesame, vegetable and animal fat	Vegetable (fresh and canned)	Fruits (dried, fresh and canned)	Ground meat	
1970	271.6	17.9	202.0	37.0	583.0	26.5	75.1	1.2	9.1	28.4	77.0	0.6	233.0
1975	257.2	57.7	220.0	11.3	641.3	*	122.1	1.2	14.4	23.1	143.0	0.5	536.0
1976	395.1	116.8	244.0	23.5	922.7	54.8	71.1	1.5	30.6	64.8	178.2	0.5	617.0
1977	331.4	196.5	161.5	119.0	922.9	91.1	154.3	1.3	34.1	136.5	210.0	0.7	748.0
1978	420.1	304.7	404.1	53.4	1 334.3	100.0	90.3	2.6	53.6	206.5	218.8	1.5	1 230.0
1979	703.0	400.0	442.0	320.0	2 055.1	120.0	124.7	1.8	81.2	74.2	313.1	1.5	1 570.0
1980	606.3	663.0	356.1	1 229.3	3 023.4	141.0	291.1	3.4	100.0	246.0	493.9	0.4	2 628.0

Source: References 1-3.

Table 3 Production of Agricultural Commodities

Year	Wheat			Vegetables			Melons			Green fodder area 10^3 ha	Total prod. of fruit (1000t)	Prod. of dates (1000t)	Milk. prod. (1000t)	Fish & Egg Prod. (1000t)	Production of nitrogenous fertilizer (1000t)
	Area 10^3 ha	Prod. 10^3 t	t/ha	Area 10^3 ha	Prod. 10^3 t	t/ha	Area 10^3 ha	Prod. 10^3 t	t/ha						
1970	100.0	150	1.5	14.2	518.8	36.5	*	360.0	*	*	263.7	220.0	149	27.1	11.2
1975	62.6	132	2.1	41.9	690.0	16.5	14.4	297.7	20.7	44.7	418.1	337.2	127	33.5	99.8
1976	74.0	93	1.3	37.0	518.3	14.0	13.3	254.4	19.1	41.3	319.2	256.9	129	37.2	81.6
1977	71.6	125	1.8	42.2	607.7	14.4	15.7	305.7	19.5	46.4	450.1	382.3	232	37.3	111.0
1978	60.0	120	2.0	33.1	440.3	13.3	11.4	156.5	13.7	34.4	496.1	411.4	256	43.0	121.0
1979	79.3	147	1.9	44.1	539.0	12.2	15.1	179.0	12.0	*	501.0	417.0	268	46.0	137.5
1980	84.2	158	1.9	27.2	546.0	11.6	16.4	168.0	10.2	*	513.0	422.0	275	56.0	*

*Date not available. Source: References 1-3.

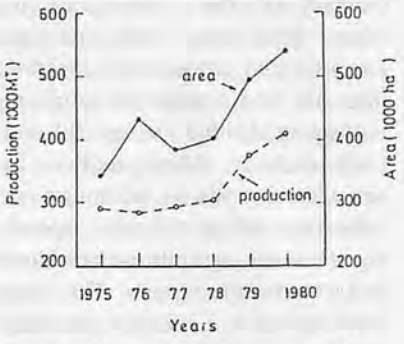


Fig. 2 Total production and area of cereal crops.

cultural commodities have risen steadily over the past decade (**Table 2**), **Table 3** shows that the production of agricultural commodities has either gone down or has not experienced an appreciable increase. Some more land has been reclaimed and brought under cultivation during the past years but overall production level did not increase (**Fig. 2**). This can be attributed to the farmer loosing interest in farming, poor farming techniques and management, and lack of appropriate crop production research along with other limiting factors. This all reflects that the Kingdom has to depend heavily on agricultural commodities imports to meet the domestic needs.

Manpower

The lack of skilled manpower is the number one problem in the country. There are about 4 million working people and approximately 80% of them are non-Saudi, mostly working in areas other than agriculture. Therefore, manpower shortage must remain a significant constraint on the true national development and agricultural sector in particular.

Saudi Arabia has two major resources – oil and people. By the end of the century oil will be almost depleted or become a less important commodity – but she will still have people. The government is striving to motivate and educate the people to change them into a productive nation and redirect the economy while there is still time so that the coming generations could inherit a truly productive society.

A bedouin who used to work hard to have his ends meet, feels proud to be a custodian of world energy resources. This feeling has changed his working attitude. Presently, under the government protection plan, a Saudi can make US$1 000-2 000 per month, practically without doing anything. An ordinary individual who cannot do any other job, under certain government provisions, he can import foreign laborers to let them loose in the Kingdom to find work anywhere, and the Saudi sponsor collects US$150-300 from each per month. Individuals with some business know-how have become millionaires in the shortest possible time in the Kingdom.

Government Emphasis on Agriculture

For diversification of the economy base, the government realized that a development program should emphasize the most important sectors which are vital to the socio-economic development of the coun-

try to build a strong economic structure. To achieve this, many projects such as land reclamation, building irrigation and drainage canals, and building dams, are under way. The government provides huge sums of interest-free loans and grants liberal subsidies to farmers. Local producers and foreign investments are encouraged especially in joint-ventures with the public or private capital. Incentives given to farmers to increase agricultural production include:

1. Land grants.
2. Import subsidies on agricultural machinery, irrigation pumps, poultry and dairy equipment, feed and fertilizer.
3. Production subsidies on different agricultural commodities, e.g., wheat, sorghum, barley, rice maize, and newly planted dates.
4. Price support for different agricultural commodities.
5. Farm home loans.

Land Distribution: Lease and Ownership – Land grants have always been a method of distributing wealth in the country. The distribution of virgin land increased very sharply in the late 1950's and early 1960's. In an attempt to curb cash outflows, virgin tracts of land were often given to individuals in place of cash. The land was then redeemed through sale to the government for projects. Estimated average size of holding in cultivated areas did not exceed 2.5 ha before the new land grant policy was introduced in 1968.

The new land distribution policy places all the public land under the supervision of the Department of Land Utilization, Ministry of Agriculture and Water. The public land for distribution should be free of ownership of individual or communal land, free of any judiciary conflict, located outside the municipality limits, and potentially good for agricultural production. Beneficiaries can be Saudi individuals or companies.

The agricultural land suitability studies are conducted by the Department of Land Utilization and if the area is declared potentially good for agriculture, then the area is distributed among the interested farmers. Based on the number of applicants, area availability, agricultural interest and potential of applicants, the area is distributed with hectareage range of 5-20 ha. For companies, the hectareage can be up to 40 ha or more.

After the land lease is approved, the individuals or companies have to develop the area and bring under cultivation different crops within five years. If the Ministry finds out that the leased land is not being developed according to the terms and conditions set, the lease can be cancelled. On the other hand, if the ministry is satisfied with the performance of the individuals/companies for the land development, then the ownership is entrusted to them. Some of the cancelled leases are re-leased to other farmers showing interest and potential for the land development.

The present status of agricultural land holdings by size is given in **Table 4**, which indicates that average size of holdings has risen to about 7 ha due to the new land reform policy.

Farm Credit Facilities – The landmark in the agricultural development came about by the establishment of the Agricultural Bank which offers a wide range of incentives to farmers covering all aspects of agriculture. In general, the bank finances the whole agricultural sector needs, from land preparation to product marketing, without charging any interest. Tremendous increase of bank's developmental capital over the past decade is shown in **Fig. 3** which clearly indicates the important role of the bank in the agricultural development.

When a farmer is alloted a piece of agricultural land, he then becomes eligible for the land development grants from the bank, a minimum of US$150 000. The bank credit does not include the price of digging of the well on the farm. Separate grant is allocated for well-drilling which easily runs up to US$0.5 million. (Deep well turbines are installed to reach the aquifer with unlimited water supply at the depth of 450-500 m). A farmer is further entitled to a loan of US$90 000 if he builds a house on the farm. These credit loans are

Table 4 Distribution of Agricultural Land Holdings by Size

Land holding class (ha)	Holders		Area	
	Number	%	1 000 ha	%
0.5 – 1.0	69238	38.33	33.08	2.73
1.1 – 5.0	71162	39.40	151.45	12.48
5.1 – 10.0	17714	9.80	118.82	9.79
10.1 – 20.0	12354	6.84	164.73	13.58
20.1 – 50.0	6574	3.64	188.18	15.51
50.1 – 100.0	1999	1.11	127.93	10.54
100.1 – 200.0	986	0.55	123.63	10.19
200.1 – 500	442	0.24	120.06	9.89
over 500	153	0.09	185.58	15.29
Total	180 622	100.00	1 213.46	100.00

Source: Reference 1

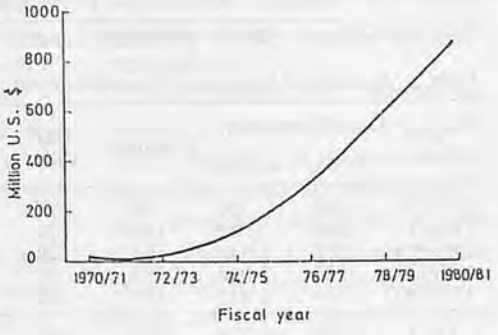


Fig. 3 Development of Saudi Arabian Agricultural Bank's capital.

interest free and could be for a short term of 2-5 years, but generally are long term loans up to 25 years. The bank loans can be received in terms of cash or kind depending on the farmer's demand.

The government is also supporting programs for adopting modern agricultural techniques in order to increase production. The government allocated special funds: US$3.35 billion in the Second Five-Year Plan (1975-80) and US$6.21 billion in the Third Five-Year Plan (1980-85) for agricultural development in addition to the yearly budget of the Ministry.

Financial Help Program – In addition to the above farm credits, the government provides further financial assistance to the farmers to encourage them to use modern agricultural practices on the farms to improve their income and help maintain the agricultural product profit at a low level. This program is cosponsored by the Ministry of Finance and National Economy and Silos and Flour Mills Corporation in addition to the Ministry of Agriculture and Water and Agricultural Bank. This financial help program is designed to encourage the agricultural and animal production and production of agricultural machinery and other equipment within the Kingdom.

Subsidy for Agricultural Machinery Development – The Ministry of Agriculture and Water maintains a strict control over the farm machinery prices between the sellers and farmers. The Ministry pays through the Agricultural Bank to the farmers 50% of the price of any agricultural machinery purchased on its CIF value and 25% for any implement. The sellers are compensated by the Ministry for their profits and are held responsible to provide spare parts, service, maintenance, and training to the farmers for the type of product they sell. This subsidy covers machinery and equipment related to cultivation, irrigation and drainage, plant protection, animal and poultry production, and the fishing industry.

Table 5 shows the loans and subsidies extended to farmers through the Agricultural Bank over the period of 1970-80 in terms of cash and kind. The agricultural machines and equipment extended through the bank between fiscal years 1975/76-1979/80 are given in **Table 6.**

Land Rental Policy – This is another approach to encourage the public land distribution and its development. The ministry grants a lease of huge areas of public land, declared suitable for agricultural production, to commercial bodies with capital and technical know-how to develop the area on modern lines. Such land rentals have been made at several places but Al-Hers and Al-Kharj projects, both sites located about 150 km east of Riyadh, have shown proven success of the policy. On these sites, both extensive and intensive agriculture is being practiced. This system

Table 5 Loans Received by Farmers and Subsidies from the Agricultrual Bank (SAAB) Unit: US$ million

Fiscal year	Medium term loan transactions by SAAB			Subsidies paid through SAAB		Medium term loan movement by SAAB			Short term loan extended
	Cash	Kind (Farm machinery)	Total	Total	Farm machinery allocation (%)	Total	Farm machinery allocation	%	
1970/71	*	*	*	*	*	4.13	0.07	1.70	2.92
71/72	*	*	*	*	*	4.20	0.15	3.57	*
72/73	*	*	*	*	*	4.91	0.43	8.76	*
73/74	*	*	*	2.85	21.40	9.64	1.56	16.18	*
74/75	*	*	*	13.63	19.37	40.68	5.86	14.41	2.04
75/76	*	*	*	39.58	31.73	76.82	13.98	18.20	2.34
76/77	*	*	*	53.58	23.12	138.99	23.84	17.15	4.91
77/78	33.27	2.60	35.87	71.05	18.76	1594.0	29.40	1.85	12.86
76/79	43.55	2.93	46.48	112.97	26.88	204.06	50.91	24.95	4.55
79/80	50.70	3.43	54.13	128.12	26.44	325.28	65.55	20.15	6.84
Totals	127.52	8.96	136.48	421.78	25.10	2402.71	191.75	8.00	36.46

*Data not available. Source: References 1 and 5.

Table 6 Agricultural Equipment Extended through Loans by SAAB between Fiscal Years 1975/76–1979/80

Fiscal year	Tractors		Combines	Hay balers	Shovels and ploughs	Drills	Levelling coulters and blades	Trailers and others	Loan value for farm machinery (US$ million)	Total med. term loan (US$ million)	%
	Track	4-wheel									
1975/76	306	700	86	29	759	22	77	63	14.0	76.8	18.2
1976/77	264	785	168	24	1 672	20	251	230	23.8	139.0	17.2
1977/78	233	1 216	144	29	75	33	–	220	29.4	159.6	18.4
1778/79	411	2 068	183	59	4 485	114	1 024	1 479	50.9	204.1	24.9
1979/80	254	2 011	315	62	5 075	147	1 216	2 862	65.6	325.3	20.2
Total	1 468	6 789	896	203	12 066	336	2 568	4 854	183.7	904.8	20.3

Source: Reference 5.

seems more profitable than the individual leases and ownerships. Therefore, the Ministry wants to enhance this approach through public as well as private ownership. Actually, this is a joint government-cum-private ownership policy, and much of the farm credits are given to the company and the government still keeps one fourth of the land share.

Educational and Training Institutes – The Ministry of Agriculture and Water has established several training centers throughout the Kingdom where the farmers and youth are given training about the modern agricultural practices. The Ministry provides free boarding and lodging and a pocket allowance to the trainees. The government has opened 15 vocational training centers in the larger towns for the general uplift of the public. There are three agricultural colleges in the Kingdom producing general agricultural and agricultural engineering graduates. An agricultural extension program is also under way to help promote agricultural mechanization programs in the country. The Ministry also maintains some mobile training-cum-extension units to provide prompt assistance to the farmers in remote locations.

Improvements Needed for Agricultural Development

The government agricultural mechanization sponsoring programs are very generous and rather overlapping so that everyone becomes interested in farming. And, if a farmer manages to get all the possible government allowances for land development, well-drilling, machinery and equipment, housing, etc, a poor bedouin becomes rich overnight. No doubt, this might be the way for the government to distribute the oil wealth among the people but this is changing people's attitudes towards work; desert-loving and hard working people are becoming comfort-loving and moving toward urban centers. Presently, when a farmer gets a lease/ownership of a piece of agricultural land and secures all the possible aid from the government, first of all he builds a huge villa, a desert resort for his family picnic on the farm which certainly contributes nothing towards the actual development. The farmer also becomes entitled to import some laborers to work at the farm, this keeps the farmer ignorant of the essential training to run the farm himself. When the oil wealth runs out, the foreign labor will disappear. This means that a Saudi farmer will start learning farming practices about 20-25 years from now.

The government must stop the money-giving away policy until someone really demonstrates the need for it and proves to develop the land and bring the production up to certain level within a given time limit after the land is leveled and tubewell is installed. Also, the government aid should be given in steps, not in lump sums, to make sure that the process of development is being carried out properly. It might be feasible that the area declared potentially good for agriculture could be developed by the government before distribution among the different farmers. This approach could be money and time saving and the area could be developed on modern lines (correct leveling and proper irrigation and drainage system installation, etc) for which the individual farmers generally do not pay attention. A farmer showing good progress in developing the land must be rewarded, this can create a sense of competition among the farmers to work harder on the farms.

An agricultural commodity produced locally normally costs more than for the same one imported, therefore, there is not much market for the domestic produce. Government should buy the domestic produce at comparatively higher rates to encourage the farmers. This might be still another way of giving away money to the farmers but it will have some long range benefits.

The land may be leased on a family basis rather than to individuals. Some leases should be based on the family work force. Also, a family basis rather than to individuals. Some leases should be based until after the development is complete and the government finally entrusts the farmer the ownership of the area. This practice will keep the individual farmer in touch with the farming practices.

Agricultural production in most of the cultivated areas is generally low due to soil salinity and alkalinity, lack of nutrients, proper irrigation and drainage networks, fertilizers, improved seeds adaptable to the area, and pest, disease, and weed control. Also, very little is known regarding water requirements for different crops, leaching requirements, time of planting and such other factors.

In order to raise productivity, which must be based on the results of planned research, more agricultural research stations are needed to investigate and find answers to these problems with a view to improving the present state of agriculture. Also, research scope should not be limited to conventional crops only. There are several desert plants which can provide human food and other industrial supplies (*eg* Jojoba) may be successfully grown in the Kingdom's marginal lands.

Even though the country has enough capital to invest, an adequate research on socio-economic impact of farm mechanization is still necessary not only to give clear direction to the mechanization program but also to keep a watch on the implementation of the programs and to assess the effect on different segments of the

society. A study of such aspects of farm mechanization will help clarify the issues involved to assist the policy makers.

Presently, all the technology in the Kingdom is imported and is being applied without any change or modification. This modern technology has a proven success in countries where it was developed, tested, and applied after an extensive research. Keeping in view the regional limiting factors, this technology cannot be applied here without modifications and some other adjustments. Therefore, research within the country is necessary to mold the available technology to fit the needs of the Kingdom. Also, the Ministry of Agriculture and Water should establish a machinery evaluation program to test and evaluate the equipment in the field for their suitability before issuing an import permit to individual companies. Such an evaluation program will help establish 'standards' for the kind of technology to be imported. (Surprisingly, there are more than two dozen tractor makes and models with power ranging from 15-90 hp imported into the Kingdom from all over the world during the past decade).

Extension service in the country is inadequate and needs to be improved to keep the farmers informed about new farming techniques. Cooperative farming is another venture in which the government can play an important role in bringing about a suitable technological change in the farming practices.

Government should pay special attention to the education of rural people. Adult education, 4-H type programs for youth, and additional vocational institutes will help equip people with modern farming practices. The establishment of demonstration plots in the agricultural areas, like Al-Herd and Al-Kharj would also be very helpful.

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Reader's Letter

Many thanks for the complimentory copies of 'AMA'. I have been receiving after one of our papers, 'Pneumatic Separator For Various Rice Fractions' appeared (Vol.14, No.2, 1983) in the journal.

The editorial, 'Some Lessons From Central Africa' has appeared at a right time and this should be read by all those living in the developing world.

The editorial is well written. Please accept my congratulations for the grim reminder you have given to the people of the developing world.

With kind regards,

Very sincerely yours,

Prem Chand

Indian Institute of Technology
Kharagpur, India

The Nebraska Test Procedure — Using the Results

by
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Abstract

This paper is a follow-up to an earlier article which appeared in the AMA Journal (Vol. XV, No.3). The paper explains the use of the data obtained from Nabraska Tractor Test Report. In the example used, two different tractors are compared. Proper evaluation of the data is extremely important when tractor selection is concerned.

Introduction

In a previous article (1), the readers were acquainted with the test procedure of the Nebraska Test Laboratory. This article will provide some information on the use of the reports. Obviously, it is impossible to foresee all the possible questions and give satisfactory answers to all the problems which might occur in actual evaluations of tractors for particular conditions. What we want to do here is to suggest some guidelines on the use of the reports.

In general, there are a number of criteria which determine the choice of a particular model for a specific condition. A few are listed here – not necessarily in any specific order of importance.

1. Acquisition cost.
2. Estimated operating cost (fuel, oil, filters, tires, etc.).
3. Availability of parts and service – present and future.
4. Sophistication of model(s) compared to necessary and available level of education training.
5. Availability of operator training.
6. Suitability of performance to particular needs.

We shall concern ourselves only with the last question since this is the only one the tractor test data can give answers to.

Performance

By tractor performance data we mean to indicate those parameters which are usable by the farm operator; those which he can measure as work output in field operations. Thus, performance can be measured by all or some of the following parameters:

a. Drawbar power in various gears.
b. Drawbar pull in various gears.
c. Forward speeds available and gear spacing.
d. Type of transmission – power shift, partial power shift, manual mechanical shift, shuttle forward – reverse shift, etc.
e. Available tire options.
f. Lugging ability.
g. Power-take-off power at standard speed.
h. Fuel consumption at various loads.
i. Oil consumption.
j. Sound level – operator and bystander.
k. Weight and weight distribution – ballasting.

The relative importance of each of the performance parameters will depend upon the user's conditions and preferences and will be discussed in the following paragraphs. Several of the parameters are interrelated and thus cannot be separated.

Looking at the Report

In **Figs. 1** and 2, two tractor test reports are shown. The only changes made from the originals are that all references to tractor make and model have been removed. In **Table 1** some of the parameters of Tractor A and Tractor B are listed.

As can be seen, tractor A had a 16 speed gear box with a two speed on-the-go power shift. Tractor B was tested as a front-wheel-assist tractor. Tractor A was a regular 2-Wheel drive. Drawbar tests on a hard surface such as concrete do not show the advantages of a front-wheel-assist (FWA). This is due to the difference in circumferential speed between front and rear wheels. The front wheels move slightly faster in order to facili-

NEBRASKA TRACTOR TEST - TRACTOR A
16 SPEED

POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crank shaft speed rpm	Fuel Consumption gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Temperature °F (°C) Cooling medium	Air wet bulb	Air dry bulb	Barometer inch Hg (kPa)
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—567 rpm)								
56.18 (41.89)	2500	3.669 (13.889)	0.458 (0.279)	15.31 (3.016)	184 (84.2)	54 (12.5)	75 (23.8)	28.850 (97.422)
Standard Power Take-off Speed (540 rpm)—One Hour								
55.69 (41.53)	2382	3.555 (13.457)	0.447 (0.272)	15.67 (3.086)	184 (84.4)	53 (11.4)	74 (23.4)	28.855 (97.439)
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
48.73 (36.34)	2552	3.312 (12.537)	0.477 (0.290)	14.71 (2.899)	182 (83.6)	56 (13.1)	78 (25.3)	....
0.00 (0.00)	2636	1.412 (5.345)	....	....	179 (81.7)	54 (12.5)	76 (24.4)	....
24.77 (18.47)	2594	2.358 (8.926)	0.667 (0.406)	10.51 (2.069)	180 (82.5)	52 (10.8)	73 (22.8)	....
56.95 (42.47)	2498	3.693 (13.980)	0.455 (0.277)	15.42 (3.038)	184 (84.4)	52 (11.1)	75 (23.9)	....
12.47 (9.30)	2612	1.845 (6.984)	1.037 (0.631)	6.76 (1.332)	180 (81.9)	54 (11.9)	76 (24.2)	....
36.89 (27.51)	2576	2.799 (10.595)	0.532 (0.324)	13.18 (2.597)	182 (83.3)	54 (12.5)	76 (24.4)	....
Av 29.97	**2578**	**2.570**	**0.601**	**11.66**	**181**	**54**	**76**	**28.890**
Av (22.35)		*(9.729)*	*(0.366)*	*(2.297)*	*(82.9)*	*(12.0)*	*(24.2)*	*(97.557)*

DRAWBAR PERFORMANCE

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank-shaft speed rpm	Slip %	Fuel Consumption gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Temp. °F (°C) Cool-ing med	Air wet bulb	Air dry bulb	Barom. inch Hg (kPa)
Maximum Available Power—Two Hours 9th (5L) Gear											
46.66 (34.80)	3674 (16.34)	4.76 (7.67)	2499	7.60	3.602 (13.635)	0.541 (0.329)	12.96 (2.552)	185 (85.0)	47 (8.1)	56 (13.3)	28.885 (97.540)
75% of Pull at Maximum Power—Ten Hours 9th (5L) Gear											
37.26 (27.78)	2789 (12.41)	5.01 (8.06)	2567	5.47	3.138 (11.880)	0.590 (0.359)	11.87 (2.339)	185 (84.8)	51 (10.4)	61 (16.0)	28.760 (97.118)
50% of Pull at Maximum Power—Two Hours 9th (5L) Gear											
25.53 (19.04)	1860 (8.27)	5.15 (8.28)	2589	3.63	2.586 (9.788)	0.710 (0.432)	9.87 (1.945)	184 (84.4)	49 (9.4)	61 (16.1)	28.885 (97.540)
50% of Pull at Reduced Engine Speed—Two Hours 12th (6H) Gear											
25.51 (19.02)	1861 (8.28)	5.14 (8.27)	1469	3.56	1.801 (6.818)	0.495 (0.301)	14.16 (2.790)	184 (84.2)	52 (10.8)	65 (18.3)	28.870 (97.490)
MAXIMUM POWER IN SELECTED GEARS											
39.25 (29.27)	5688 (25.30)	2.59 (4.16)	2541	14.76	5th (3L) Gear			184 (84.2)	43 (6.1)	47 (8.3)	28.870 (97.490)
44.98 (33.54)	5005 (22.26)	3.37 (5.42)	2500	11.39	6th (3H) Gear			184 (84.4)	45 (7.2)	51 (10.6)	28.880 (97.523)
46.22 (34.46)	4817 (21.43)	3.60 (5.79)	2499	10.66	7th (4L) Gear			185 (85.0)	44 (6.7)	48 (8.9)	28.690 (96.882)
46.75 (34.86)	3692 (16.42)	4.75 (7.64)	2499	7.32	8th (4H) Gear			186 (85.3)	45 (7.2)	49 (9.4)	28.680 (96.848)
47.35 (35.31)	3719 (16.54)	4.77 (7.68)	2500	7.44	9th (5L) Gear			186 (85.3)	45 (7.2)	48 (8.9)	28.680 (96.848)
47.26 (35.24)	2860 (12.72)	6.20 (9.97)	2498	5.46	10th (5H) Gear			185 (85.0)	45 (7.2)	49 (9.4)	28.680 (96.848)
47.53 (35.44)	2634 (11.72)	6.77 (10.89)	2499	5.08	11th (6L) Gear			185 (85.0)	44 (6.7)	48 (8.9)	28.690 (96.882)
46.94 (35.00)	2016 (8.97)	8.73 (14.05)	2500	3.86	12th (6H) Gear			185 (85.0)	44 (6.7)	48 (8.9)	28.690 (96.882)

Fig. 1 Test report of Tractor "A".

Department of Agricultural Engineering

Dates of Test:

Manufacturer:

FUEL, OIL AND TIME: Fuel No. 2 Diesel **Cetane No.** 47.0 (rating taken from oil company's inspection data) **Specific gravity converted to 60°/60°** *(15°/15°)* 0.8420 **Fuel weight** 7.010 lbs/gal *(0.840 kg/l)* **Oil SAE** 15W-40 **API service classification** CD, CC, SD **To motor** 1.718 gal *(6.502 l)* **Drained from motor** 1.334 gal *(5 048 l)* **Transmission and final drive lubricant**

transmission and hydraulic fluid **Total time engine was operated** 39.5 hours.

ENGINE: Mak **Type** four cylinder vertical **Serial No.** 4239DL07557761CD **Crankshaft** lengthwise **Rated rpm** 2500 **Bore and stroke** 4.19" x 4.33" *(106.5 mm x 110 mm)* **Compression ratio** 16.8 to 1 **Displacement** 239 cu in *(3920 ml)* **Starting system** 12 volt **Lubrication** pressure **Air cleaner** two paper elements **Oil filter** one full flow cartridge **Oil cooler** engine coolant heat exchanger for crankcase oil, radiator for hydraulic and transmission oil **Fuel filter** one paper element and one mesh strainer **Muffler** underhood **Exhaust** vertical **Cooling medium temperature control** one thermostat.

CHASSIS: Type standard **Serial No.** *L02350T466897* **Tread width** rear 59.8" *(1519 mm)* to 96.1" *(2440 mm)* front 57.6" *(1462 mm)* to 79.1" *(2008 mm)* **Wheel base** 89.2" *(2266 mm)* **Center of gravity** (without operator or ballast, with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from center-line of rear wheels 29.2" *(741 mm)* Vertical distance above roadway 33.5" *(851 mm)* Horizontal distance from center of rear wheel tread 0" *(0 mm)* to the right/left **Hydraulic control system** direct engine drive **Transmission** selective gear fixed ratio with partial (2) range operator controlled powershift **Advertised speeds mph** ***(km/h)*** first 1.5 *(2.4)* second 1.9 *(3.1)* third 2.1 *(3.4)* fourth 2.7 *(4.3)* fifth 3.0 *(4.9)* sixth 3.8 *(6.2)* seventh 4.1 *(6.6)* eighth 5.2 *(8.3)* ninth 5.2 *(8.4)* tenth 6.6 *(10.7)* eleventh 7.2 *(11.6)* twelfth 9.2 *(14.8)* thirteenth 10.4 *(16.7)* fourteenth 13.2 *(21.2)* fifteenth 14.0 *(22.5)* sixteenth 17.8 *(28.6)* reverse 2.3 *(3.8)*, 3.0 *(4.8)*, 3.2 *(5.2)*, 4.1 *(6.6)*, 4.6 *(7.5)*, 5.9 *(9.5)*, 6.3 *(10.1)*, 8.0 *(12.8)* **Clutch** single dry disc operated by foot pedal **Brakes** wet disc hydraulically actuated and operated by two foot pedals which can be locked together **Steering** hydrostatic **Turning radius** (on concrete surface with brake applied) right 131.0" *(3.33 m)* left 131.0" *(3.33 m)* (on concrete surface without brake) right 147.0" *(3.73 m)* left 147.0" *(3.73 m)* **Turning space diameter** (on concrete surface with brake applied) right 271.0" *(6.88 m)* left 271.0" *(6.88 m)* (on concrete surface without brake) right 303.0" *(7.70 m)* left 303.0" *(7.70 m)* **Power take-off** 540 rpm at 2382 engine rpm.

LUGGING ABILITY IN 9th (5L) GEAR

Crankshaft Speed rpm	2500	2251	2004	1749	1501	1249	1003
Pull—lbs *(kN)*	3719 *(16.54)*	3960 *(17.61)*	4243 *(18.87)*	4471 *(19.89)*	4650 *(20.68)*	4719 *(20.99)*	4570 *(20.33)*
Increase in Pull %	0	6	14	20	25	27	23
Power—Hp *(kW)*	47.35 *(35.31)*	45.10 *(33.63)*	42.69 *(31.84)*	38.94 *(29.03)*	34.50 *(25.73)*	29.03 *(21.64)*	22.69 *(16.92)*
Speed—Mph *(km/h)*	4.77 *(7.68)*	4.27 *(6.87)*	3.77 *(6.07)*	3.27 *(5.26)*	2.78 *(4.48)*	2.31 *(3.71)*	1.86 *(3.00)*
Slip %	7.44	7.99	8.70	9.40	10.09	10.32	9.86

TRACTOR SOUND LEVEL WITHOUT CAB	dB(A)
Maximum Available Power—Two Hours	94.5
75% of Pull at Maximum Power—Ten Hours	93.5
50% of Pull at Maximum Power—Two Hours	93.0
50% of Pull at Reduced Engine Speed—Two Hours	88.5
Bystander in 16th (8H) gear	86.5

TIRES, BALLAST AND WEIGHT		With Ballast	Without Ballast
Rear Tires	—No., size, ply & psi *(kPa)*	Two 16.9-30; 6; 16 *(110)*	Two 16.9-30; 6; 16 *(110)*
Ballast	—Liquid (each)	170 lb *(77 kg)*	None
	—Cast Iron (each)	None	None
Front Tires	—No., size, ply & psi *(kPa)*	Two 7.50-16; 6; 44 *(305)*	Two 7.50-16; 6; 44 *(305)*
Ballast	—Liquid (each)	None	None
	—Cast Iron (each)	20 lb *(9 kg)*	None
Height of Drawbar		19 in *(485 mm)*	19 in *(485 mm)*
Static Weight with Operator	—Rear	4980 lb *(2259 kg)*	4640 lb *(2105 kg)*
	—Front	2210 lb *(1002 kg)*	1270 lb *(984 kg)*
	—Total	7190 lb *(3261 kg)*	6810 lb *(3089 kg)*

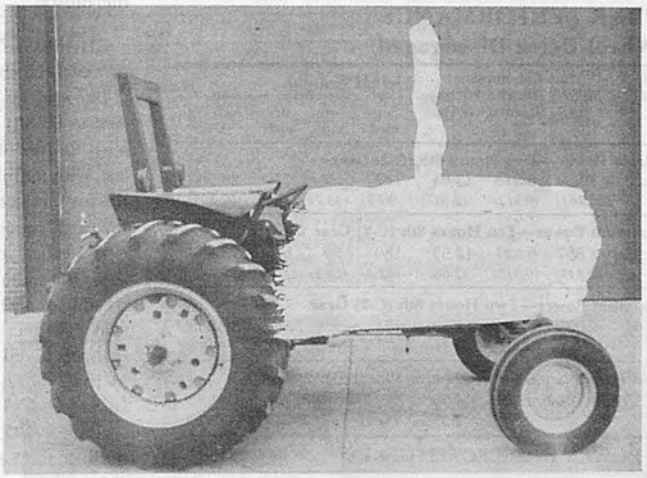
REPAIRS and ADJUSTMENTS: No repairs or adjustments.

REMARKS: All test results were determined from observed data obtained in accordance with SAE and ASAE test codes or official Nebraska test procedure. For the maximum power tests, the fuel temperature at the injection pump was maintained at 141°F *(60.6°C)*. Eight gears were chosen between 15% slip and 10 mph *(16.1 km/h)*.

We, the undersigned, certify that this is a true and correct report of official Tractor Test 4

LOUIS I. LEVITICUS
Engineer-in-Charge

K. VON BARGEN
W. E. SPLINTER
L. L. BASHFORD
Board of Tractor Test Engineers



NEBRASKA TRACTOR TEST - TRACTOR B

12 SPEED

POWER TAKE-OFF PERFORMANCE

Power Hp (kW)	Crank shaft speed rpm	Fuel Consumption gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Temperature °F (°C) Cooling medium	Air wet bulb	Air dry bulb	Barometer inch Hg (kPa)
MAXIMUM POWER AND FUEL CONSUMPTION								
Rated Engine Speed—Two Hours (PTO Speed—643 rpm)								
58.00 (43.25)	2400	3.637 (13.768)	0.439 (0.267)	15.95 (3.141)	183 (83.7)	66 (19.2)	75 (24.0)	28.740 (97.051)
Standard Power take-off Speed (540 rpm)—One Hour								
52.81 (39.38)	2017	3.092 (11.704)	0.410 (0.249)	17.08 (3.365)	181 (82.7)	66 (19.1)	75 (23.9)	28.730 (97.017)
VARYING POWER AND FUEL CONSUMPTION—Two Hours								
50.33 (37.53)	2451	3.074 (11.636)	0.427 (0.260)	16.37 (3.225)	178 (80.8)	66 (18.9)	75 (23.9)	....
0.00 (0.00)	2539	1.162 (4.399)	....	....	166 (74.7)	66 (18.9)	75 (23.9)	....
25.65 (19.13)	2497	1.938 (7.336)	0.529 (0.322)	13.23 (2.608)	170 (76.7)	66 (18.9)	75 (23.9)	....
58.00 (43.25)	2400	3.648 (13.809)	0.440 (0.268)	15.90 (3.132)	183 (83.9)	66 (18.9)	75 (23.9)	....
12.95 (9.66)	2522	1.492 (5.648)	0.806 (0.490)	8.68 (1.710)	168 (75.3)	66 (18.9)	75 (23.9)	....
38.09 (28.40)	2472	2.456 (9.297)	0.451 (0.275)	15.51 (3.055)	176 (79.7)	66 (18.9)	75 (23.9)	....
Av 30.84 *Av (23.00)*	**2480**	**2.295** *(8.688)*	**0.521** *(0.317)*	**13.44** *(2.647)*	**173** *(78.5)*	**66** *(18.9)*	**75** *(23.9)*	**28.750** *(97.084)*

DRAWBAR PERFORMANCE
(Front Wheel Drive Disengaged)

Power Hp (kW)	Drawbar pull lbs (kN)	Speed mph (km/h)	Crank-shaft speed rpm	Slip %	Fuel Consumption gal/hr (l/h)	lb/hp.hr (kg/kW.h)	Hp.hr/gal (kW.h/l)	Temp. °F (°C) Cooling med	Air wet bulb	Air dry bulb	Barom. inch Hg (kPa)
Maximum Available Power—Two Hours 8th (C-2) Gear											
48.15 (35.91)	3548 (15.78)	5.09 (8.19)	2400	7.23	3.530 (13.361)	0.513 (0.312)	13.64 (2.687)	182 (83.3)	59 (14.7)	71 (21.4)	28.990 (97.895)
75% of Pull at Maximum Power—Ten Hours 8th (C-2) Gear											
38.66 (28.83)	2721 (12.10)	5.33 (8.57)	2452	4.93	2.857 (10.813)	0.517 (0.315)	13.53 (2.666)	180 (82.1)	59 (14.8)	63 (17.4)	28.885 (97.540)
50% of Pull at Maximum Power—Two Hours 8th (C-2) Gear											
26.36 (19.66)	1814 (8.07)	5.45 (8.77)	2474	3.66	2.229 (8.438)	0.592 (0.360)	11.83 (2.330)	174 (78.9)	55 (12.8)	66 (18.9)	29.050 (98.097)
50% of Pull at Reduced Engine Speed—Two Hours 10th (D-1) Gear											
26.37 (19.66)	1815 (8.07)	5.45 (8.77)	1431	3.50	1.793 (6.789)	0.476 (0.290)	14.70 (2.896)	179 (81.7)	59 (14.7)	74 (23.1)	28.985 (97.878)
MAXIMUM POWER IN SELECTED GEARS											
36.99 (27.59)	5749 (25.57)	2.41 (3.88)	2453	14.82	5th (B-2) Gear			173 (78.3)	45 (7.2)	49 (9.4)	29.260 (98.807)
47.99 (35.79)	5432 (24.16)	3.31 (5.33)	2401	12.50	6th (B-3) Gear			180 (82.2)	46 (7.8)	49 (9.4)	29.270 (98.840)
48.54 (36.20)	4726 (21.02)	3.85 (6.20)	2398	10.38	7th (C-1) Gear			181 (82.8)	55 (12.8)	63 (17.2)	28.970 (97.827)
49.29 (36.76)	3628 (16.14)	5.09 (8.20)	2400	7.11	8th (C-2) Gear			181 (82.8)	53 (11.7)	60 (15.6)	28.960 (97.794)
48.81 (36.40)	2569 (11.43)	7.12 (11.47)	2401	4.84	9th (C-3) Gear			181 (82.8)	57 (13.9)	66 (18.9)	28.970 (97.827)
47.80 (35.64)	1970 (8.76)	9.10 (14.65)	2397	3.72	10th (D-1) Gear			182 (83.3)	58 (14.4)	68 (20.0)	28.980 (97.861)

Department of Agricultural Engineering

Dates of Test:

Manufacturer:

FUEL, OIL AND TIME: Fuel No. 2 Diesel **Cetane No.** 47.0 (rating taken from oil company's inspection data) **Specific gravity converted to 60°/60°** *(15°/15°)* 0.8404 **Fuel weight** 6.998 lbs/gal *(0.839 kg/l)* **Oil SAE** 20-20W **API service classification** SE-SF, CC-CD **To motor** 1.990 gal *(7.535 l)* **Drained from motor** 1.792 gal *(6.785 l)* **Transmission and hydraulic lubricant** Shell Donax TD or equivalent **Front axle lubricant** SAE 80/90 gear oil **Total time engine was operated** 45.0 hours.

ENGINE: Make **Type** three cylinder vertical **Serial No.** D3200-A-19386 **Crankshaft** lengthwise **Rated rpm** 2400 **Bore and stroke** 4.29" × 4.53" *(109 mm × 115 mm)* **Compression ratio** 17 to 1 **Displacement** 196 cu in *(3219 ml)* **Starting system** 12 volt **Lubrication** pressure **Air cleaner** one paper element **Oil filter** one full flow paper cartridge **Fuel filter** one paper element and water separator **Muffler** vertical **Cooling medium temperature control** one thermostat.

CHASSIS: Type front wheel assist **Serial No.** M5950DTF-U50039 **Tread width** rear 55.9" *(1420 mm)* to 79.5" *(2020 mm)* front 55.9" *(1420 mm)* to 63.8" *(1620 mm)* **Wheel base** 83.3" *(2115 mm)* **Center of gravity** (without operator or ballast, with minimum tread, with fuel tank filled and tractor serviced for operation) Horizontal distance forward from center-line of rear wheels 36.3" *(921 mm)* Vertical distance above roadway 36.8" *(935 mm)* Horizontal distance from center of rear wheel tread 0" *(0 mm)* to the right/left **Hydraulic control system** direct engine drive **Transmission** selective gear fixed ratio **Advertised speeds mph** ***(km/h)*** first 1.0 *(1.6)* second 1.3 *(2.1)* third 1.8 *(2.9)* fourth 2.3 *(3.6)* fifth 2.9 *(4.6)* sixth 3.9 *(6.3)* seventh 4.5 *(7.2)* eighth 5.7 *(9.2)* ninth 7.8 *(12.5)* tenth 9.8 *(15.8)* eleventh 12.5 *(20.1)* twelfth 17.1 *(27.5)* reverse 0.8 *(1.2)*, 1.6 *(2.6)*, 3.3 *(5.2)*, 7.1 *(11.5)* **Clutch** single plate dry disc operated by foot pedal **Brakes** multiple wet disc operated by two foot pedals which can be locked together **Steering** hydrostatic **Turning radius** (on concrete surface with brake applied) right 130" *(3.3 m)* left 130" *(3.3 m)* (on concrete surface without brake) right 158" *(4.0 m)* left 158" *(4.0 m)* **Turning space diameter** (on concrete surface with brake applied) right 276" *(7.0 m)* left 276" *(7.0 m)* (on concrete surface without brake) right 331" *(8.4 m)* left 331" *(8.4 m)* **Power take-off** 540 rpm at 2017 engine rpm.

REPAIRS and ADJUSTMENTS: No repairs or adjustments.

Fig. 2 Test report of Tractor "B".

LUGGING ABILITY IN 8th (C-2) GEAR

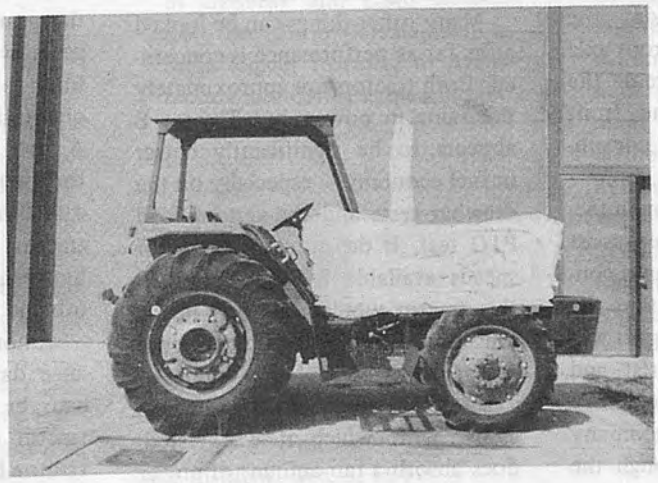
Crankshaft Speed rpm	2400	2163	1914	1684	1436	1198
Pull—lbs *(kN)*	3628 *(16.14)*	3808 *(16.94)*	4090 *(18.19)*	4330 *(19.26)*	4512 *(20.07)*	4509 *(20.06)*
Increase in Pull %	0	5	13	19	24	24
Power—Hp *(kW)*	49.29 *(36.76)*	46.39 *(34.60)*	43.76 *(32.63)*	40.43 *(30.15)*	35.71 *(26.63)*	29.78 *(22.21)*
Speed—Mph *(km/h)*	5.09 *(8.20)*	4.57 *(7.35)*	4.01 *(6.46)*	3.50 *(5.63)*	2.97 *(4.78)*	2.48 *(3.99)*
Slip %	7.11	7.63	8.21	9.11	9.44	9.56

TRACTOR SOUND LEVEL WITHOUT CAB	dB(A)	Front Wheel Drive Disengaged dB(A)
Maximum Available Power—Two Hours	97.5	97.5
75% of Pull at Maximum Power—Ten Hours		97.0
50% of Pull at Maximum Power—Two Hours		96.5
50% of Pull at Reduced Engine Speed—Two Hours		91.0
Bystander in 12th (D-3) gear		87.0

DRAWBAR PERFORMANCE
(Front Wheel Drive Engaged)

Power Hp *(kW)*	Drawbar pull lbs *(kN)*	Speed mph *(km/h)*	Crank-shaft speed rpm	Slip %	Fuel Consumption gal/hr *(l/h)*	lb/hp.hr *(kg/kW.h)*	Hp.hr/gal *(kW.h/l)*	Temp. °F *(°C)* Cool-ing med	Air wet bulb	Air dry bulb	Barom. inch Hg *(kPa)*
Maximum Available Power—Two Hours 8th (C-2) Gear											
47.51 *(35.43)*	3340 *(14.86)*	5.33 *(8.58)*	2400	4.68	3.494 *(13.226)*	0.515 *(0.313)*	13.60 *(2.679)*	183 *(83.6)*	59 *(14.7)*	74 *(23.3)*	28.975 *(97.844)*
MAXIMUM POWER IN SELECTED GEARS											
42.66 *(31.81)*	8350 *(37.14)*	1.92 *(3.08)*	2434	14.90	4th (B-1) Gear			175 *(79.4)*	45 *(7.2)*	48 *(8.9)*	29.240 *(98.739)*
49.13 *(36.63)*	3457 *(15.38)*	5.33 *(8.58)*	2400	4.65	8th (C-2) Gear			181 *(82.8)*	52 *(11.1)*	56 *(13.3)*	28.950 *(97.760)*

TIRES, BALLAST AND WEIGHT		With Ballast	Without Ballast
Rear Tires	—No., size, ply & psi *(kPa)*	Two 16.9-28; 6; 16 *(110)*	Two 16.9-28; 6; 16 *(110)*
Ballast	—Liquid (each)	432 lb *(196 kg)*	None
	—Cast Iron (each)	360 lb *(163 kg)*	None
Front Tires	—No., size, ply & psi *(kPa)*	Two 9.5-24; 6; 30 *(205)*	Two 9.5-24; 6; 30 *(205)*
Ballast	—Liquid (each)	173 lb *(79 kg)*	None
	—Cast Iron (each)	585 lb *(265 kg)*	None
Height of Drawbar		15.5 in *(395 mm)*	15.5 in *(395 mm)*
Static Weight with Operator	—Rear	5110 lb *(2318 kg)*	3525 lb *(1599 kg)*
	—Front	4110 lb *(1864 kg)*	2595 lb *(1177 kg)*
	—Total	9220 lb *(4182 kg)*	6120 lb *(2776 kg)*



REMARKS: All test results were determined from observed data obtained in accordance with SAE and ASAE test codes or official Nebraska test procedure. For the maximum power tests, the fuel temperature at the injection pump was maintained at 145°F *(62.8°C)*. Six gears were chosen between 15% slip and 10 mph *(16.1 km/h)*. During inspection it was found that the exhaust valves of cylinders 1 and 2 were pitted.

We, the undersigned, certify that this is a true and correct report of official Tractor Test No. 1

LOUIS I. LEVITICUS
Engineer-in-Charge

K. VON BARGEN
W. E. SPLINTER
L. L. BASHFORD
Board of Tractor Test Engineers

Table 1 Parameters for Comparison

		Tractor A	Tractor B
I	Physical		
1	No. of speeds (gears)	16	12
2	No. of speeds tested	8	6
3	Power shift	2-Range	–
4	Front wheel assist – tested	No	Yes
5	Vertical distance of C.G. above roadway	85 cm	93 cm
6	Tested with Cab/ROPS (2 Post)/ROPS (4 Post)*	2 Post ROPS	4 Post ROPS
7	Standard PTO speed(s)	540 RPM	540 RPM
8	Rated engine speed	2 500 RPM	2 400 RPM
9	Fuel: specific volume-used on test	0.840 kg/l	0.839 kg/l
II	Performance		
1	Max power at rated engine speed	41.89 kW	43.25 kW
2	Power at standard PTO speed	41.53 kW	39.38 kW
3	Fuel: Specific volumetric cons. a Max Pwr	3.016 kWh/l	3.141 kWh/l
4	Fuel: Specific volumetric cons. a STD PTO speed	3.086 kWh/l	3.365 kWh/l
5	Fuel: Average spec. vol. cons. from varying load test	2.297 kWh/l	2.647 kWh/l
6	Fuel: Spec. vol. cons. from 10 HR drawbar test	2.339 kWh/l	2.666 kWh/l
7	Fuel: Spec. vol. cons. from 2 HR – 50% load – drawbar test	1.945 kWh/l	2.330 kWh/l
8	Lugging ability at 20% of rated engine speed	+14%	+13%
9	Amount of engine oil used during test	1.454L	0.75L
10	Duration of test	39.5 h	45 h
11	Coolant temp during max pwr DB – test	85.0 C	83.3 C
12	Ambient temp during max pwr DB – test	13.3 C	21.4 C
13	Sound level at operators ear – max	94.5 dB(A)	97.5 dB(A)
14	Bystander sound level	86.5 dB(A)	87.0 dB(A)

* ROPS stands for Roll Over Protective Structure.

tate steering. On a hard surface, this causes energy losses due to friction. In a loose soil, this would not occur.

In addition, when the front-wheel-assist tractor is operated in the two-wheel-drive mode, the internal resistance of the front axle and input drive shaft increase the "rolling resistance" of the front wheels compared to the conventional front axle.

One of the reasons a manufacturer will test a front-wheel-assist equipped tractor rather than a conventional 2-wheel-drive is that the sales permit and the test report will include the front-wheel-assist and the conventional two-wheel-drive tractors. This saves the company time and money even though the drawbar data show a little less efficiency.

The number of gears tested was 8 for tractor A, but note that 8th and 9th gear were very close together. On the other hand, the 9th gear is the power-shifted downshift gear from 10th gear. For those needing a very low gear, tractor B's lowest gear is considerably below the lowest gear of tractor A.

Many other things can be looked at as far as performance is concerned. Both tractors are approximately the same in power, but Tractor B appears to be significantly better in fuel economy – especially on the drawbar tests and the varying load PTO test. If the number of tractor speeds available is sufficient, then this tractor would save fuel in the long run. This would be even more so for the two-wheel drive model of Tractor B since the front-wheel assist, with which it was tested, does absorb a fair amount of power as was explained before.

The lugging ability expresses the capability of the tractor to overcome increases in resistance without having to stop and change gears. Resistance changes can be caused by the topography or varying soil characteristics in a field.

Assume for a moment that tractor A obtains the same data in a field as on the track. The tractor is being operated in the field in 9th gear at maximum power (see gear test). The pull is 16.54 kN. Most of the field is uniform but one section has been used in the past to grow potatoes and has been compacted. Let's assume further that this causes the pull to increase by 16% to 19.19 kN. The lugging ability at 80% of Rated Engine Speed (see lugging test) is 18.87 kN. Usually, when the engine is lugged down 20%, the manufacturer suggests that the tractor be operated in a lower gear. Thus, in this case, a shift-down is necessary to 7th gear which can produce a pull of 21.43 kN at rated engine speed. On the other hand, if a 10% increase in pull was required due to field conditions, there would be no need to shift down since the lugging ability (the extra pull available) is 14% at 80% rated engine speed. The lugging ability for both tractors is practically the same down to 60% of the rated engine speed.

An on-the-go power shift on all the gears or between two adjacent gears will eliminate much of the time loss which can occur if frequent shifting is required. Tractor A has power shifting capabilities for two gears (1st to 2nd, 3rd to 4th, 5th to 6th, etc). Stopping the tractor would still be necessary between 2nd and 3rd, 4th and 5th, 6th and 7th, etc.

Amongst "secondary" performance data, engine oil consumption can be of importance. Clearly, tractor A consumed more oil than tractor B. From local follow-up, we have learned that, if a tractor consumes too much oil during the test, it will do similarly in actual use. One has to look also at the total amount of oil in the engine and the

time of operation. We then find that tractor A consumed at a rate of 3.68 *l*/100 h and that has to be compared to a total amount of 6.502 liter in the engine. Tractor B used 1.67 *l*/100 h and contained 7.535 *l* in the engine. Clearly, engine A consumed much more oil. It would be expected to do that also during actual field use.

The next item we will look at is the coolant temperature. In the case of Tractors A and B, there is not much difference, but sometimes one obtains a very high coolant temperature for a test conducted at a moderate ambient temperature. This is a reason for concern especially if there are also notes in the "Remarks" section pertaining to observed engine damage, such as pitted or burned valves. One should ask the question: If this tractor ran so hot at 15°C, how hot would it run in areas where the temperature is usually about 30°C?

A last item to be discussed is the sound level. Clearly, Tractor A is quieter to the operator than Tractor B, but in both cases, the level is sufficiently high to warrant the use of ear protection. The acceleration noise or bystander noise level, however, appears to be about the same for both units. Operator protection and comfort are of great importance. Obviously, the various options such as cabs with roll-over protection or simple roll over protective structures add to the initial purchase price of a tractor. This extra cost should be balanced against increased operator efficiency. In addition, there is a future cost involved for hearing damage (noise), lung diseases (dust and pesticides), back and internal organ damage (seating), which definitely will occur in the long run.

Conclusions

We have shown a method of comparing two tractors, based on the data from the test reports. This is just one method. Another one might be the use of a "point system" for each parameter which is judged important. These parameters can include cost, physical dimensions, options available, service stations and parts availability, etc. The tractor model with the most points at the end of the analysis will be the more desirable one to purchase.

REFERENCES

1. Louis I. Leviticus. "The Nebraska Tractor Test Procedure." AMA, Vol XV, No. 3. Summer, 1984. ■■

New Co-operating Editors



Anastas Petrov Kaloyanov

Nationality: Bulgaria

Qualification:

1944 B. Sc. Agriculture, Sofia University

Experience:

Served in the Dept. of Agric. Engineering, Sofia Agric. Academy for 20 years as Asst. Prof., Assoc. Prof. and Prof. -Head of the Department.

Present Position:

Head of the Research Laboratory on Farm Mechanization, Higher Institute of Economics, Sofia. Lecturer in the Faculty of Geodesy and Land Regulation on Farm Mechanization, Sofia Higher Institute of Architecture and Civil Engineering.



Kayode C. Oni

Date of Birth: Dec. 3, 1947

Nationality: Nigeria

Qualification:

1971 B. Sc. (Agr.), Ahmadu Bello Univ., Zaria, Nigeria.
Ph. D., Kansas State Univ.,U.S.A.

Experience:

Dr. Oni has worked extensively in the areas of agric. mechanization for small- and medium-scale farming systems, development of appropriate agric. implements and soil-plant-machine dynamics.

Present Position:

Senior Lecturer, Dept. of Agric. Engineering, Univ. of Ilorin, Nigeria. ■■

ABSTRACTS

Drilling of Pelleted Paddy Seeds in Puddled Field: Maru, K.T. and S.C.B. Siripurapu, Assistant Prof. and Prof./Head, respectively, Dept. of Agric. Product Process Engineering, Gujarat Agricultural University, Anand, India

Paddy seeds of variety IR 24, were pelleted using clay loam soil particles smaller than 150 microns and tap water. A concrete mixer was used for soil coating on the paddy seeds. Laboratory tests showed that the density of pelleted paddy seeds increased and found suitable for drilling in puddled soil. Field trials of drilling of pelleted paddy seeds of different densities in separate strips indicated that the seeds with density of about 1.7 g/cc could effectively be imbeded in puddled field when they are allowed to fall freely from about 10 cm height from the seed tubes of a drill. It was observed that there was neither any seed injury nor loss by rats and birds and also they were not affected by the wave action of water.

Rainfall Erosion of Northeast Thailand: Rab, Md. Abdur, Dept. of Agric. Engineering and Basic Engineering, Bangladesh Agricultural University, Mymensingh, Bangladesh

Eleven automatic rain gauge stations were selected on the basis of length of records of available data. The minimum length of record was taken as eight years. The automatic rainfall data were analysed and erosion index values were computed by adding the kinetic energy of rain having intensity greater than 25 mm per hour. The average annual, wet-season and monthly iso-erosion index maps were produced to read the rainfall factor in Universal Soil Loss Equation. The log probabilities of annual erosion index were calculated for designing erosion control measures with the desired probability level. The monthly distribution of erosion index curves for 11 locations in Northeast Thailand were produced for use in selecting proper crop management factors.

The annual average erosion index in Northeast Thailand ranges from 9000 to 15000. The annual average erosion index at ThaTum was 1.7 times greater than that at Udon Thani. Two types of variation of erosion index in Northeast Thailand were observed, namely, seasonal variation and variation due to locality. Analysis of monthly iso-erosion index maps show that, in May erosion index increases from Udon Thani to Sakon Nakhon, in June it increases from Udon Thani to Roiet, in July it increases from Loei to Roiet, in October erosion index ranges from 500 to 1500 and it increases from Udon Thani to Nakhon Ratchasima. These variations of erosion index should be considered in the planning of erosion control measures in Northeast Thailand.

Work Capacities and Fuel Consumptions of Hand Tractors Manufactured in the Philippines: Cornelio J. Ancheta, Senior Agric. Engineer, Agric. Machinery Testing and Evaluation Center and Roberto C. Bautista, Assistant Prof. in Agric. Machinery Engineering and Technology, respectively, University of the Philippines, Los Baños, Philippines.

Test results of ten hand tractors manufactured in the Philippines were compiled and analyzed. Farmers' rice fields in Laguna and Nueva Ecija were used as test areas. Field performance data show the actual plowing capacity ranged from 0.098 ha/h to 0.25 ha/h with an average of 0.14 ha/h (or 7.86 h/ha) and the field efficiencies ranged from 53.6 to 94.4% with an average of 83.6%. Six of the hand tractors tested were gasoline-fed and the average fuel consumption was 2.49 l/h (18.73 l/h) and a specific fuel consumption of 1.89 l/h/hp. On the other hand, the four diesel-fed hand tractors had an average fuel consumption of 0.82 l/h (6.12 l/h) and an average specific fuel consumption of 1.22 l/ha/hp. Obviously, the hand tractors with diesel engines have lower fuel consumption which will offset in the long run their high initial purchase cost.

Some of the Physical Properties of Sunflower Seeds: Salokhe, V.M., Division of Agric. and Food Engineering, Asian Institute of Technology, Bangkok 10501, Thailand; Pratap Singh and K.N. Nag, Prof. and Head, Dept. of Farm Machinery and Power and Dean, respectively, College of Technology and Agric. Engineering, Udaipur 313001, India

The design of a machine for shelling the seeds is influenced by the size (length, breadth and thickness) of the seeds. With the help of a large number of measurements empirical equations are proposed to express the correlation among 3 principal dimensions for the 2 most commonly recommended sunflower varieties in India. From the measurement of either length or breadth of the seed, additional set of equations have been proposed to estimate the projected area of the sunflower seeds with a reasonable degree of accuracy. ■■

NEWS

American Society of Agricultural Engineers 1985 Summer Meeting
June 23-26, 1985
Michigan State University, East Lansing, Michigan, U.S.A.

Agricultural engineering has provided the tools to harness nature for production of the food and fiber we use daily. And according to program chairman Benson J. Lamp, ASAE President-Elect (Business Planning Manager for Ford Motor's Worldwide Tractor Operations), in "Engineering the future," new technologies will be applied to more effectively produce for mankind an enhanced quality of life.

At the 1985 ASAE Summer Meeting future technologies for engineering in agriculture were revealed. New ways to harness nature will be reported in discussion of international concerns for land forming, water flow regulators for irrigation, control of the environment in greenhouses, intelligent sensors to operate farm equipment, the storage of biomass for fuel and a comprehensive array of engineering applications to biological materials.

Meeting features: Over 350 technical presentations in 68 half-day technical sessions; More than 200 technical committees and subcommittee meetings.

Special emphasis sessions address these topics: Biomass for Energy Today; Electric Energy Utilization in Agriculture; Engineering for Potatoes; Management of High Tech Agricultural Machines and Systems; Tillage Procedures and Machines.

The following Awards were presented during the Socieety's 1985 Summer Meeting.

Kishida International Award



Harry D. Henderson, most recently Chairman, Department of Soils, Irrigation and Mechanization, at the American University in Beirut, Lebanon, has been awarded the 1985 Kishida International Award by the American Society of Agricultural Engineers (ASAE).

Henderson is honored for his efforts and achievements in areas of international agricultural engineering. Following about seventeen years as an educator at U.S. institutions, including Iowa State University of Wisconsin, the honoree began his career of international service as a training officer with the Food and Agriculture Organization of the United Nations in Rome, Italy.

Later appointments for Henderson included the directorship of Iran's Agriculture College at Ahwaz plus advisor in mechanization to the government of Nigeria and, later, to the University of Swaziland. He also has served as visiting lecturer at various universities. He is particularly commended for his efforts in developing and implementing curricula for overseas educational programs.

Other Awards

Lawrence H. Hodges, Technical Affairs Consultant, Racine, Wisconsin and Neil F. Bogner, Consulting Engineer, EBASCO Services Inc., Springfield, Virginia have received the 1985 Cyrus Hall McCormick Medal and the 1985 John Deer Gold Award, respectively, from the ASAE.

International Conference/AG ENG 86
September 1-4, 1986, Noordwijkerhout, The Netherlands

The conference will be held in Leeuwenhorst Congress Center at Noordwijkerhout, The Netherlands. Leeuwenhorst is a modern, comprehensive congress center.

Apart from introductory and concluding plenary sessions there will be six parallel sets of lecture sessions, including the following subject areas:

Environmental improvement
a) Agricultural waste management
b) Tractors - agricultural machinery
c) Buildings and structures

Design and development of new products and methods for farm management
a) Sensors, robotics and data processing
b) Operational research, modelling and decision making
c) Crop production and processing

For further information contact the Conference Manager:

Mr. A.P.S. de Jong, IMAG
P.O. Box 43
6700 AA Wageningen
The Netherlands

2nd International Fair for Agricultural Industry – AGROTEC '85
November 13-24, 1985, Lima, Peru

AGROTEC'85 will be held with-

in the framework of XVI PACIFIC INTERNATIONAL TRADE FAIR.

The announced policy of priority for agriculture, the availability of credit lines from the World Bank, the Development Bank and international financing institutions, and the continued urgency to capitalize this important sector of the country's economy, are eloquent reasons for holding AGROTEC'85.

The Banco Agrario del Peru, which played an important part in AGROTEC'84, processing 542 applications for financing for capital goods acquired during the Fair for a total of approximately US$20,000,000 has already indicated to us its interest in putting even greater effort into AGROTEC' 85, so as to continue the success already begun.

AGROTEC'85 will include Seminars, Congresses and international high-level meetings to spur the transfer of technology and business contacts with foreign countries.

For details contact:
Mr. Rafael Talavera
International Promotions Manager
Pacific International Trade Fair
P.O. Box 4900, Lima, Peru

Indian Society of Agricultural Engineers Silver Jubilee Convention
October 28-30, 1985
Bhopal, India

Convention Programme

The major programmes of the Convention would be presentation and discussions on technical papers, demonstration and National Exhibition of Improved Agricultural Machinery. About 500 professional engineers are expected to participate in the convention.

Technical Sessions

Presentation of papers would be done under the following groups in the form of Special Seminars:

1. Farm Power and Machinery
2. Soil and Water Engineering
3. Process and Food Engineering
4. Dairy Engineering
5. Energy in Agriculture

Call for Papers

Foreign delegates may send their papers by 15th August.

For details contact the convener
Shri N.S.L. Srivastava
Central Institute of Agricultural Engineering (ICAR)
Nabi Bagh, Berasia Road,
Bhopal-462 018, M.P., India

A New Programme of Training in "Manufacturing for Agricultural and Industrial Development" commencing in October 1985 by Cranfield Institute of Technology, U.K.

Aim – To provide training in engineering manufacture to meet agricultural and rural development needs in less industrialised countries.

Background – There is a desire in the developing countries of the world to promote the development, both of agriculture and manufacturing industry. Agricultural mechanization is regarded as an important concomitant of agricultural development, but imported machinery is often regarded as inappropriate or ill-adapted to local use. Fostering local manufacture of agricultural machinery is seen as a way of simultaneously promoting agricultural production and developing a Nation's manufacturing capability (Lagos Plan for Action). Such development can and does take place alongside the establishment of locally based international companies which themselves require the services of well trained local personnel.

Good examples of this process at work can be seen in Asian countries such as the Republic of Korea, the Philippines and Thailand. Here, the recognition of a lack of suitably trained people with knowledge of production engineering has led to the development of the Regional Network for Agricultural Machinery (RNAM).

In response to this need, Cranfield Institute of Technology plan to introduce a new programme of training in "Manufacturing for Agricultural and Industrial Development", commencing in October 1985. The programme will last for two years and will lead to the award of an MSc degree.

The organisers of the programme recognise that an MSc degree is not an appropriate training for a small enterpreneurs directly engaged in manufacture in a developing country. However, such manufacturers are often in desperate need of reliable and practical advice in order to improve their manufacturing capability, their product design, control of quality, purchasing, marketing and distribution of the product and business organisation. Such advisors would normally be employed in specialist government departments or by agencies specially set up to offer an adivsory service, or indeed by financial organisations who need to monitor an enterprise before supplying the necessary loan.

A similar need for appropriately trained personnel arises with locally based international companies, which on account of their larger size require the services of knowledgeable professional people, preferably nationals of their own country.

Programme Structure – The programme lasts for a full two years, commencing in October. The main objective of the first year programme of study is to provide a thorough grounding in the principles and practice of manufacturing technology. During their first year the students will engage in taught courses with practical training in all important aspects of production engineering within the School of Production Studies.

During this period, students will be based mainly in the Department of Agricultural Engineering at Silsoe. The programme consists of ten units of study. A group project will be undertaken in the first four week period of the summer term, and may take the form of a management simulation exercise or may be concerned with the design and planning of manufacture of a piece of equipment. The special study will take the form of an individual research or design project, undertaken principally during the summer period, and on which an individual dissertation will be submitted in September.

The normal entry requirement will be a good honours degree in an appropriate subject, preferably any branch of engineering or related physical subject. Candidates from other backgrounds such as agriculture will be considered, but would be expected to have an adequate knowledge of mathematics and physics.

The taught courses consist of ten units of study, which are backed up with a programme of practical classes, demonstrations, tutorials, visits and directed work. This is then followed by a period of placement with a UK manufacturer to provide direct experience of commercial production and management techniques.

The main objective of the second year programme is to provide a general knowledge of the application of manufacturing technology to meet the needs of agriculture and rural development.

Howard Rough Terrain Tractor "SERBATREK"

The "Serbatrek" is a tractor designed to carry loads in difficult terrain no matter if it's hilly or swampy. It is very strongly built to stand up to the very tough conditions it's designed for and has a strong full size tubular chassis. The Serbatrek can have a variety of bodies from simple flat top, hydraulic tipping buckets, net frame and gantry hoist, fertiliser distributor, provision for fitting sprayers, hydraulic buckets, etc. Designed primarily for carrying tasks, it has a low centre of gravity and low ground pressure. The hydrostatic transmission makes it very versatile and the new unique track system is



fully serviceable rather than having to change an entire track when it wears out.

Specification:

Engine – Lombardini electric start 26hp air cooled diesel engine direct coupled to the hydrostatics. Displacement – 1120 cm^3, RPM–3000, Weight –110 kg.

Payload – up to 2000 kg

Ground pressure – 3.8 psi with 1500 kg payload

Gardient – Hard to measure but appears to be better than 3 in 1 with 1000 kg payload

Dimensions (HxWxL) – 1950x1800x2950mm

Gross weight – 1270 kg

For details refer to

Howard Alatpertanian Sdn. Bhd.
P.O. Box 8, Batu Caves
Selangor, Malaysia ■■

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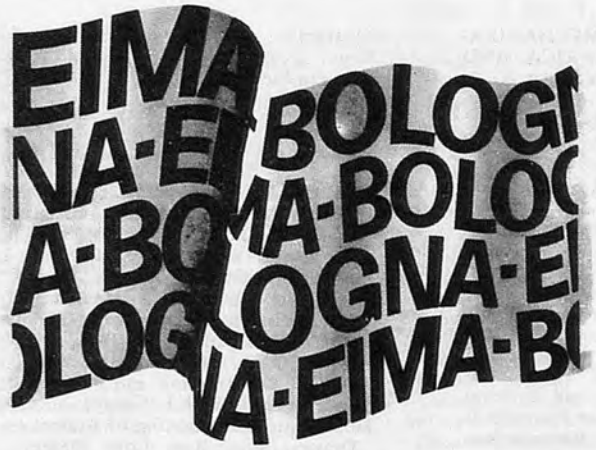
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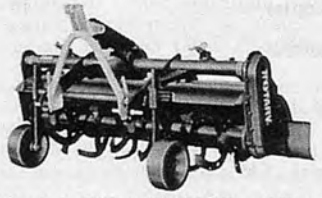
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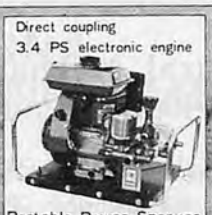
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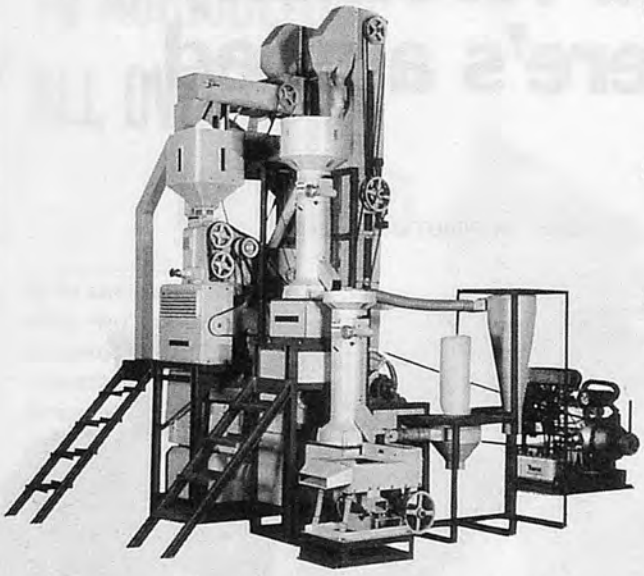
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1. More simplified and solidified structure
   Total structure of the unit has been simplified and solidified by means of reasonable vertical construction, which makes the required installation space less than 1/3 of many other conventional machineries.
2. Only two bucket elevators
   Since newly developed epocal tray type paddy separator eliminated discharge process of the mixture of paddy and husked rice, relative devices like bucket elevator etc. could be omitted.
3. Trouble-free operation for a long period
   Power transmission system of this unit has high efficiency because each machine is driven by each drive pulley of counter shaft. Power transmission system designed for simplicity and durability makes it possible to operate this unit trouble-free for a long period.
4. Easier and simpler to operate
   Simple operating principle and construction of this unit make operation and adjustment easy for everybody. This unit can be operated either a diesel engine or an electric motor. This enables you to install the rice milling unit conveniently anywhere you like.



YAMAMOTO MFG.CO.,LTD.

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Japanese Agricultural Machinery Catalogue '85

This bi-annual Catalogue is published in odd-numbered years. This 1985 edition introduces the latest models and designs of Japanese agricultural machines, equipment and facilities in 140 black/white photographs in 32 pages. Detailed specifications of each product are provided in 126 pages. It lists 250 leading machinery manufacturers in a directory that is conveniently indexed by trade and brand names of the product.

Other features in Japanese include recent breakthroughs and innovations incorporated in the design and functions of the new models.

The catalogue measures 18 cm x 25.6 cm, in limp cover and sells for ¥7,300 (sea mail) and ¥8,500 (air mail).

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Kubota products provide power, economy and versatility wherever there's a need.

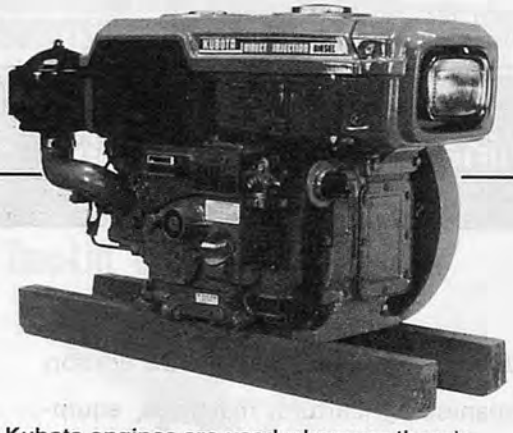
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