International specialized media for agricultural mechanization in Asian developing countries.

AMA

AGRICULTURAL MECHANIZATION IN ASIA

VOL. XI, NO. 2, SPRING 1980

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Telex: 0265-7165

Headquarters
21-10, Nishi 2-chome, Hanyu, Saitama 348 Japan
Phone: (0485)61-2111 Telex: 2942-462

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AMA

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ADVERTISING
(Tel. 03/291-3672)
Shuji Kobayashi, Manager (Head Office)
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Advertising Rate : 250 thousand yen per a page

CIRCULATION
(Tel. 03/291-5718)
Soichiro Fukutomi, Manager
Editorial, Advertising and Circulation Headquarters,
7,2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo, 101 Japan

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This is the 27th issue since the issue, Spring of 1971.

Editorial

Farm Mechanization in Retrospect

This issue of the AMA marks the first decade of its world-wide crusade for the cause of agricultural mechanization when it made a debut in the Spring of 1971. Without claiming a *lion's share* of the great progress that farm mechnization and its dissemination have achieved over the last 10 years, it can be gainsaid that the AMA has contributed its rightful share in mechanizing agriculture – thanks to the support and encouragement from its readers, co-editors and experts amound the world. In commemorating its 10th anniversary issue, the AMA re-dedicates itself to contributing even more to the promotion of agricultural mechanization.

To be sure, agricultural mechanization is not only better understood but also better appreciated today than it was 10 years ago. Today, there is a clear tendency that mechanizing agriculture is not necessarily breeding unemployment. Rather, it is creating employment opportunities let alone accelerating agricultural productivity, improving the economy and making farming a pleasant task instead of a back-breaking chore. There is ample evidence to indicate that, indeed, farm machineries have played and will continue to play its major influence in the agricultural breakthroughs that the developed and developing countries have achieved.

It is opportune to mention the First Korean International Agricultural Machinery Fair held in Seoul on March 31 – April 6, last, which I had the fortune of attending. The Fair was truly impressive: a wide range of new types and models of farm machines from many industrialized countries were displayed and demonstrated to a huge international audience that includes heads of state. The most impressive feature of the Fair, however, is the 7-year (1979–1986) scheme of the government of the Republic of Korea to supply its fast-developing agriculture with a total of 2,160,000 units of farm machines of all types! Quite naturally, the financial outlay for this scheme is equally awesome. If this ambitious Korean venture proves one thing, it is that the government leaders fully recognize the valuable prop that agricultural machineries have since been providing the recent breakthrough in agricultural and economic development of that country.

But this dramatic Korean agricultural mechanization scheme is a difficult model for many countries to emulate considering the huge financial requirement, among other things. However, it highlights the fact that more and more, government leaders should look to farm mechanization as an important tool for achieving the development impetus that agriculture deserves.

In retrospect, therefore, both the AMA's first decade and the recent Korean Fair leave a telling message to AMA's readers, co-editors and experts: the promotion of agricultural mechanization must be a continuing process because it is that important to the development of agriculture, in particular, and to the economy, in general.

Chief Editor
Yoshisuke Kishida

April, 1980
Tokyo

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Evaluation of Selected Upland Crops Establishment Techniques

by
Jai Singh
Graduate Student
Agricultural and Food Engineering Division
Asian Institute of Technology
Bangkok, Thailand

J.A. McMennamy
Agricultural Engineer
International Rice Research Institute
Los Baños, Philippines

Gajendra Singh
Associate Professor
Agricultural and Food Engineering Division
Asian Institute of Technology
Bangkok, Thailand

Introduction

Improvement in seeding methods can increase yields by establishing uniform crop stands and facilitating more effective crop care and harvesting. Limited water resources and variable climatic conditions found in many areas of the tropics make planting on schedule an important operation. The slow traditional planting methods limit the area that the farmers can plant at the optimum time.

In South and Southeast Asia the average farm size is 1.5 to 2.0 hectares. The most popular crop in this region is paddy and 20 to 27 percent of the total rice grown in Indonesia, India, Bangladesh and Philippines is upland rice (De Datta et al., 1974). To meet the growing need of grain, more than one crop is being grown on the same field.

Survey findings of different upland farming areas in the Philippines show that high labor requirement, particularly for seeding and weeding, is the most serious production constraint (Villaruel and Duff, 1977 and Prabowo, 1977). Since farmer's constraints in production include not only cost, labor and time but also inadequacy of proper tools and equipment, there is a high potential for mechanizing upland cropping operations to improve land and labor productivity and reduce physical stress.

The optimum number of plants per unit area for different crops depends on a number of factors among which availability of plant nutrients is of considerable importance (Arnon, 1972). Regardless of climate, variety and nitrogen fertilizer application, higher grain yield of paddy is obtained by increasing the plant density. The grain yield increases at a diminishing rate as plant density increases up to a certain point and then starts levelling off. The higher the rate of nitrogen fertilizer application, the smaller is the value of critical plant density (Nguu, 1977). The optimum number of corn plant population varies between 3 and 5 plants/m^2. At a lower nitrogen rate a lower population is required whereas at a higher nitrogen level a higher plant population is required for maximum yield (Lang et al., 1956). Seventy five cm rows are best suited for corn and lodging is greater for plants in 100 cm rows (Pendleton et al., 1961). A population density of 300,000 plants/ha gives the maximum mungbean yield in the wet season. In the dry season, however, the highest yield is obtained from a population density of 400,000 plant/ha (Cagampang et al., 1977). The grain yield of mungbean is not significantly affected by the spacings (50 cm, 25 cm). In the absence of mulch the yield of mungbean decreases as the rate of fertilizer increases (Carandang and Umali, 1975).

Though many types of planters and drills are available most of them are not suited to small farmers in this region because of the high initial costs. The International Rice Research Institute, Manila, Philippines, has developed a five row multi-crop upland seeder which can be used for a variety of upland crops, including upland paddy. The International Institute of Tropical Agriculture, Ibadan, Nigeria, has developed a single row, manually drawn punch for zero tillage and mulch conditions.

Both of these machines are evaluated under Philippine conditions. Effect of the seeding techniques is studied for: time and rate of emergence, yield, power and labor requirements and weed infestation and associated costs of control. The crops selected for the study were upland rice, corn and mungbean.

The IRRI Multicrop Upland Seeder

The multicrop upland seeder consists of 5 hoppers for seed and five for fertilizer, drive and feed mechanism, seed tubes, furrow openers and presswheels (**Fig. 1**). The hopper is mounted on the rear portion of the seeder frame with the feed mechanism fixed underneath. The press wheels are ground wheels used to drive the cam on the shaft that in turn drives the oscillating frame through the rocker arm. The rocker arm can be engaged or disengaged through a roller to stop seeding during turnings on headlands.

Metering plates are pinned on the frame driven by the cam through the rocker arm. The seed tubes are rigidly attached below the feed mechanism and extended to the furrow openers by two telescoping flexible plastic tubes. The furrow openers are attached by U-shaped brackets to the tool bar while the assembly is installed on the middle of the seeder by two vertical bar extensions.

Features

The seeder can be operated by a power tiller or animal, and seeds and fertilizer are applied in the same operation. Multicropping and intercropping are possible by changing the various metering plates. Row-to-row distance, hill-to-hill distance and seeding depth are adjustable. Assembly, disassembly, adjustments, cleaning and operation are simple.

The IITA Punch Planter

With the assistance of Volunteers for International Technical Assistance (VITA), IITA has developed a punch planter which can be used for seeding various upland crops without tillage. Six injectors are installed on the periphery of a wheel through which seeds are placed in the soil. A press wheel is attached to the axle which squeezes the holes made by the injectors. The metering mechanism consists of a roller with grooves on periphery and various crops can be seeded by changing the metering roller. Hill-to-hill distance is fixed at 25 cm, but it can be increased to 50 cm by sealing the alternate grooves on the metering roller. On the headlands it can be raised on the presswheel so that seeds are not metered (**Figs. 2** and **3**).

Features

The VITA punch planter is manually operated, having no adjustments, is easy to assemble, disassemble and clean, and can be easily operated by one man. Multicrop seeding is possible by changing the metering roller.

COMPONENT PARTS LIST

REF.	REQD	DESCRIPTION	REF.	REQD	DESCRIPTION
1	1	RUNNING BOARD ASSEMBLY	10	1	MAIN FRAME ASSEMBLY
2	1	MARKER ASSEMBLY	11	1	CAM ASSEMBLY
3	1	SCRAPER ASSEMBLY	12	1	PRESS WHEEL ASSEMBLY
4	2	RETURN SPRING	13	1	ROCKER ARM ASSEMBLY
5	1	HOPPER ASSEMBLY	14	5	SEED TUBE ASSEMBLY
6	5	BRUSH CUT-OFF ASSEMBLY	15	1	FURROW OPENER ASSEMBLY
7	5	METERING PLATE	16	1	HITCH ATTACHMENT
8	1	OSCILLATING FRAME ASSY	17	1	CASTER WHEEL ASSEMBLY
9	1	FURROWER LOCK ASSEMBLY			

Fig. 1 Schematic drawing of multicrop seeder

Fig. 2 VITA/IITA punch planter in transport position

Fig. 3 VITA/IITA punch planter in working position

Fig. 4 Clod size distribution of various plots

Methodology

Three different experiments were conducted on three different crops, namely upland rice, corn, and mungbean at the IRRI experimental farm. In the tillage plots no herbicide was used for weed control while for zero tillage (used for IITA punch planter), paraquat at a rate of 0.75 kg a.i./ha was sprayed for weed control. Before starting all the experiment, the weeds and residue of the previous crops were mowed. Each experiment was replicated four times and experiments were laid out according to the randomized complete block design. Before the field experiments, both machines were calibrated for various crops in the laboratory.

Experiment 1: Upland rice

An IRRI 5-hp tiller was used for land preparation. Plots which were sown by the IRRI seeder or the traditional method were plowed once and rotavated four times. Two rates of nitrogen (60 kg, 115.9 kg) were used in the experiment; row-to-row distance was maintained at 30 cm in all the seeding methods. In the traditional method of paddy seeding, well-prepared land was harrowed with a wooden harrow known as "lithao" and then seed and fertilizer were broadcasted. It was harrowed again to mix the seed with the soil. In the punch planter seeded plots, basal fertilizer was applied manually at a distance of 3 to 5 cm from the seed hills.

Experiment 2: Corn

Land preparation was done with the help of a 62.3-hp, 4-wheel tractor. Tillage plots were plowed once (6" deep) and were rotavated 3 times. Three levels of nitrogen (56.1 kg, 86.1 kg and 116.1 kg) were used. Zero tillage plots were irrigated before seeding so that the punch planter could penetrate the soil. In the furrow seeded plots, furrows were made 10-12 cm deep and 75 cm apart, 3 to 4 seeds per hill were sown at intervals of 50 cm, fertilizer was applied near the hills, and then the furrows were covered manually.

Experiment 3: Mungbean

Preplanting operations for this experiment were the same for experiment 2 (corn), except only 2 levels of fertilizer were included (0-0-0 and 25.6–25.6–25.6 kg of nitrogen, phosphorous and potash). Row-to-row distance was maintained at 50 cm. The furrow seeding method used was similar to that used for corn except the seeds were drilled continuously rather than in hills.

Results and Discussion

Machine Performance

In the laboratory, calibration for paddy at a seed rate of 102 kg/ha and a complete fertilizer (14–14–14) rate of 215 kg/ha was obtained with the IRRI seeder. For corn with 75 cm row spacing and 50 cm hill spacing it is not possible to apply fertilizer (14–14–14) at a rate of 215 kg/ha with the same seed plate, hence, separate plates adjacent to the seed plates were used to deliver the fertilizer at a distance of 10 cm from the hill. Laboratory calibration gave a seed rate of 16 kg/ha and a fertilizer rate of 217 kg/ha. For mungbeans

the laboratory calibrated seed rate was 23.8 kg/ha and the fertilizer rate was 212 kg/ha. After passing through the seeder the viability of paddy seed reduced by 1 percent; there was no effect on corn viability but the viability of mungbean was reduced by 1.5 percent.

The punch planter when calibrated under laboratory conditions, gave a seed rate of 101.4 kg/ha for paddy, 15.6 kg/ha for corn and 24 kg/ha for mungbean. After passing through the punch planter, paddy seed viability was reduced by 2.0 percent, there was no effect on corn viability but the viability of mungbean seeds was reduced by 3.5 percent.

The clod size distribution of tillage plots is shown in **Fig. 4.** For paddy, the seeder had a field capacity of 9 hr/ha with a field efficiency of 51 percent. The seeder had a positive slip of 12 percent which resulted in a seed rate of 84 kg/ha and a complete fertilizer rate of 185 kg/ha. The average pull (using 4 furrow openers) was 120 kg at a seeding depth of 1.5 to 2.5 cm while the maximum pull observed was 160 kg.

For corn, the field capacity of the seeder was 5.7 hr/ha (75 cm row) with a field efficiency of 67 percent. The positive slip was 14 percent and it delivered only 13.8 kg/ha of seed and 186 kg/ha of complete fertilizer. Even though the depth of seeding was 3 to 4 cm, the pull required for the machine was the same as for paddy in experiment 1. This was because of lower soil moisture content in comparison to paddy plots.

For mungbean the seeder had a field capacity of 6.1 hr/ha with a field efficiency of 68 percent and a positive slip of 13.5 percent. It delivered only 20.6 kg/ha of seed and 183 kg/ha of complete fertilizer. The seeding depth varied from 1.5 to 2.5 cm and the average pull required was 95 kg while the maximum observed pull was 141 kg (3 furrow openers).

Fig. 5 Germination rate of paddy at various treatments

The punch planter delivered seed at the same rate in the field as in the laboratory but there are two major problems in its operation:

1. Soil stuck to the tip of the injectors, if not cleaned after every 5 minutes, clogged the injector and, consequently, the seed did not fall.
2. Though a press wheel is provided for covering the seed, it was found that the seed-soil contact was not satisfactory thus causing poor germination of the paddy.

The field capacity of the punch planter was found to be 17 hr/ha for paddy, 14.3 hr/ha for corn and 16.3 hr/ha for mungbean and the field efficiencies were found to be 66 percent, 84 percent and 77 percent, respectively. One man can handle the machine easily.

In the traditional method of paddy seeding three persons were needed and it took 10.3 hr/ha for seeding. Furrow seeding of corn required 3.3 machine-hr/ha and 70.6 man-hr/ha. For mungbean seeding 7.7 machine-hr and 72.7 man-hr/ha were needed. Man-hr for furrow seeding of corn and mungbean, include the labor requirements for furrow making.

Germination

Paddy germination in plots sown in the traditional method and in IRRI seeder sown plots started after 5 days of seeding but in the punch planter sown plots it started after 7 days. The plots sown by the IRRI seeder had a maximum germination of 75 percent and were completed in 9 days after seeding. Germination of plots sown in the traditional method reached up to 62% in 9 days but the punch planter seeded plots could germinate only up to 52% after 14 days of seeding **(Fig. 5)**.

Corn germination started after 4 days of seeding and was completed in 3 days in all 3 methods of seeding. Furrow seeded plots and IRRI seeder seeded plots had the same germination rate but the punch planter seeded plots had significantly lower germination rate **(Fig. 6)**.

Mungbean germination started after 2 days of seeding and was completed after 6 days. The IRRI seeder seeded plots and the furrow seeded plots had the same germination but the punch planter seeded plots had comparatively lower germination rates **(Fig. 7)**.

Fig. 6 Germination rate of corn

Fig. 7 Germination rate of mungbean at various treatments

Weed Growth

With paddy the weed infestation in the punch planter seeded plots was 8 to 12 times higher than in the other plots. The effect of basal nitrogen application on dry weed matter was not significant. The first weeding was done 22 days after seeding and the second weeding was done 40 days after seeding.

With corn, the weed growth in punch planter seeded plots was 3 to 5 times higher than in the other plots. Since the quantity of the basal fertilizer in all the plots was the same, the fertilizer effect is not known.

For mungbean, punch planter seeded plots had 5 to 8 times more weed infestation compared to the other plots. Plots with fertilizer had higher weed emergence but the difference was not significant.

Yield

Paddy seeded by the IRRI seeder had higher yields than the other two seeding methods, but the differences were not significant between plots seeded in the traditional method and IRRI seeder seeded plots. Plots seeded by the punch planter had yields below normal because of higher weed infestation which suppressed the initial growth of the crop. Another reason for the lower plant population in punch planter seeded plots was poor germination. The effect of nitrogen is significant in all three methods of seeding. For the punch planter seeded plots the weed growth was almost the same at both fertilizer levels but the higher nitrogen level might have contributed to better crop growth (Table 4).

Corn had the highest yield for furrow sown plots but the difference between the three seeding methods at the same nitrogen level was not significant. The yield difference between 56.1 kg N and 86.1 kg N as well as 86.1 kg N and 116.1 kg N was not significant although there was a significant yield difference at 56.1 kg N and 116.1 kg N. For the punch planter seeded plots, though there was an increase in yield as the nitrogen levels were increased, the differences were not significant. The reason is that the higher weed growth in the punch planter seeded plots might have utilized the nitrogen fertilizer supplied for the crop (Table 5).

In mungbean at the zero fertilizer level there was no significant yield difference in three seeding methods but when 25.6 kg each of nitrogen, phosphorous and potas-

Table 1 Weed Dry Weight and Weeding Labor Requirements for Paddy as Affected by Seeding Methods and Basal Nitrogen Fertilizer

Seeding Method	Weed Dry Matter (g/m^2)		Labor Man-hr/ha
	0 kg N	25.9 kg N	
IRRI seeder	19.5 b	25.9 b	601
IITA punch planter	235.8 a	237.2 a	1804
Traditional	24.8 b	31.0 b	656

*Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 2 Weed Dry Weight and Weeding Labor Requirements for Corn as Influenced by Seeing Methods

Seeding Method	Weed Dry Matter (g/m^2)*	Labor Man-hr/ha
IRRI seeder	22.7 b	52
IITA punch planter	75.4 a	615
Furrow seeding	21.9 b	52

*Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 3 Weed Dry Weight and Weeding Labor Requirements for Mungbean as Influenced by Seeding Methods and Basal Fertilizer Level

Seeding Method	Weed Dry Matter (g/m^2)*		Labor Man-hr/ha
	0 NPK	25.6 kg NPK	
IRRI seeder	18.6 b	28.3 b	220
IITA punch planter	130.1 a	158.0 a	755
Furrow seeding	18.5 b	28.0 b	220

*Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 4 Grain Yield of Paddy as Influenced by Sowing Method and Fertilizer Rates

Seeding Method	Yield of Paddy (kg/ha)*	
	60 kg N	115.9 kg N
IRRI seeder	3005 b	3694 a
IITA punch planter	535 c	1012 d
Traditional	2838 b	3540 a

*Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 5 Grain Yield of Corn as Influenced by Seeding Methods and Fertilizer Rates

Seeding Method	Yield of Corn (kg/ha)*		
	56.1 kg N	86.1 kg N	116.1 kg N
IRRI seeder	3289 d	3751 abcd	3871 abc
IITA punch planter	3352 cd	3458 bcd	3513 abcd
Furrow seeding	3400 bcd	3911 ab	4006 a

*Means followed by a common letter are not significantly different at 5% level by DMRT.

Table 6 Grain Yield of Mungbeans as Influenced by Seeding Methods and Fertilizer Rates

Seeding Method	Yield of Mungbean (kg/ha)*	
	0–0–0 N P K	25.6–25.6–25.6 N P K
IRRI seeder	672 b	985 a
IITA punch planter	785 b	804 b
Furrow seeding	703 b	1078 a

*Means followed by a common letter are not significantly different at 5% level by DMRT.

sium were applied, the yield for punch planter seeded plots was significantly lower than that of the IRRI seeder sown plots or furrow seeded plots. This lower yield was the result of higher weed growth which might have utilized the fertilizer applied on the crop (Table 6).

Conclusions

The following conclusions can be drawn on the basis of the experiments conducted.

1. There is no significant difference in yield between seeding in furrows and the IRRI seeder in corn and mungbean.
2. In paddy the germination of the IRRI seeder sown plots is better because of good soil-seed contact.
3. The VITA/IITA punch planter can be used for zero tillage but it needs some improvement for better soil-seed contact and for the application of pre-emergent herbicides.
4. One spray of paraquat at a rate of 0.75 kg a.i./ha is not sufficient to control weeds in the zero tillage system, hence some other inexpensive chemicals or combination of chemicals and commercially available need to be identified.
5. Since there is positive slip in the IRRI seeder the metering plates should be modified to correct the fertilizer and seed rates.

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Tillage and Energy Demand: Irrigated Crop Production in Semi-Arid and Arid Regions

by
Rüdiger Krause
Senior Research Engineer
Institute of Agricultural Machinery
The Federal Research Centre for Agriculture
Bundesallee 50, 3300 Braunschweig
Federal Rep. of Germany

Abstract

Soil cultivation and management have a basic function in irrigated crop production. Proper timing, decisive for a high productivity, is related closely to the workability and trafficability of soil. The efficiency of tillage equipment is increasing with the level of mechanization but at the same time the energy input related to the yields is increasing. Plot size and accessability of fields are preventing an efficient use of four-wheel tractors.

Introduction

About 220 Mio. ha or 15% of the world's arable land are under irrigation. Most of this area is in the semi-arid and arid regions of the world, more than 50% (mainly surface irrigation) in developing countries with a high population pressure and a general shortage of arable land. The irrigated area is still extending inspite of severe problems in many of the existing systems and an increasing shortage of suitable farm water.

The high investment of the irrigation system itself and the operation costs can be justified only by a high productivity through high yields and a close crop rotation. To gain that target, generally, a relatively high level of inputs (seed, fertilizer, plant protection, energy, equipment and management) is necessary.

Cultivation Targets

Because the soil itself is an integral part of the irrigation system (**Fig. 1**) and most of the problems of irrigation systems are caused by high water losses and inappropriate soil management, soil cultivation has a basic function in irrigated crop production.

Whereas the general aims of cultivation are equal to those of rainfed agriculture, priority must be given to the tasks caused by the specific conditions of irrigation systems:

– application of high rates of irrigation;
– application of high rates of salt with irrigation water;
– continuous wet-dry-rhythm of the soil;
– small plots according to the water delivery, infiltration rate, leveling and inclination of plots;
– increased weed pressure;
– close crop rotation;
– increased production of organic matter, including roots and plant residue; and
– additional labour demand.

Therefore, the main targets of soil cultivation should be:

– equal water distribution;
– high take up rate and water holding capacity;
– suitable internal drainage of soil;
– reduction of upwards water movement and evaporation;
– controlled water flow;
– creation of stable soil aggregates of suitable size; and
– breaking of soil crusts.

For surface irrigation systems a number of additional field operations before, during and after planting that must be considered are:

– leveling dams after harvest of preceding crops, incorporation of plant residue, mechanic weed control;
– sub-soiling and leaching if needed;
– primary tillage and secondary tillage, including weed control;
– leveling of surface;
– bordering;

Fig. 1 Soil as an integral part of the irrigation system

Fig. 2 Pumping of water

– cross checking;
– furrowing (in case of furrow or corrugation irrigation);
– shaping of dams;
– crust breaking; and
– pumping and distribution of water **(Fig. 2)**.

In wet rice (paddy) production the aims of cultivation and, therefore, the operations are different. Here the main operation is puddling of the flooded soil to destroy the soil structure and to create a compact layer for minimum water loss when the field is flooded.

For all operations suitable tools and implements are generally available from multi-purpose hand hoe, and wooden animal drawn plow to the sophisticated tractor and implement systems. Nevertheless the available choice and proper use are still difficult.

The basic problems of cultivation are:
– proper timing of operations,
– availability of energy,
– appropriate depth, intensity frequency and accuracy of cultivation,
– accessability of plots, and
– management.

Proper Timing and Energy Demand

Proper timing when water is available means cultivation immediately after harvest, losing as little time as possible for the next crop. In Egypt, for instance, an average of nearly two crops per year (cropping intensity 1.9) is possible. And in Taiwan up to four crops per year (sweet potatoes, rice, vegetables, rice) are grown through proper timing.

Crucial especially for the bottleneck "soil cultivation" is the available power (human, animal or engine) related to the arable land which in most of the developing countries is still far below the demand identified by FAO as 1.5 kW/ha for fully mechanized

irrigated crop production or the minimal demand of 0.5 to 0.75 kW/ha. **Table 1** shows that Sri Lanka, for instance, seems to be close to saturation; Japan has five to ten times the minimum at hand and Bangladesh less tehan 0.01. It shows also the available mechanical energy per man. In India, 20 farmers have to share 1 kW; in Egypt, where 100% of the arable land is irrigated, five farmers have only one kW available !

Fig. 3 shows in greater detail the relation between human, animal and mechanical energy. In Egypt some 20% human and 30% animal energy is still used.

The capacity of the different sources of energy varies greatly **(Fig. 4)**.

One man can cultivate from 0.02 ha to 0.1 ha per day (600 kJ) by handhoe. Additional seasonal labour to break the labour peak of tillage is rare even in overpopulated countries.

The area to be cultivated by a family of 1.5 active workers is limited to about 1 ha. Because cultivation has to be done twice at least, including leveling, bordering and cross-checking, 2.5 workers devoting full time to seedbed preparation need up to 8 weeks when weather and soil conditions allow working all the time.

With a pair of bullocks the daily ploughed acreage is about three times as high, 0.03 ha up to 0.3 ha and the quality of tillage is better. The farm area can be extended from 2.0 ha to 2.5 ha. Nevertheless, in most of the developing countries the number of draft animal is decreasing, especially in irrigated areas because fodder production for draft animals is too expensive in irrigation schemes (a pair of bullocks needs more than half a ha for fodder production) and grazing area is no longer available.

Power tillers are mainly used for puddling in paddy fields in Southeast Asia. The efficiency is 0.15 ha to 0.5 ha per day, nearly double that of a pair of bullocks and five times as a man with the handhoe. Furthermore, the power tiller can be used in two or three shifts per day with two or three operators so that the daily acreage can be easily doubled. Furthermore the powertiller can be used for transport and as general source of energy.

The four-wheel tractor (50 kW) has the highest efficiency with 1.0 ha to 2.4 ha/day in one shift under favorable conditions, nearly 25 times the human efficiency.

Some 25 ha of land can be cultivated by one tractor. But the average size of irrigated farms in the developing countries is 1 ha – 2 ha only. Plot size and field accessability are often limiting factors in the use of tractors.

Table 1. Available Mechanical Power

Country	Total - 10^3 kW	kW per ha Available-land	kW per ha Harvested land	kW per man
Bangladesh	15	*	*	0.01
Brazil	6,105	0.15	0.14	0.42
Colombia	905	0.22	–	0.11
Egypt	930	0.39	0.20	0.22
India	6,525	0.04	0.48	0.05
Japan	43,348	7.76	7.23	7.23
Korea, Rep. of	1,278	0.58	0.50	0.25
Nepal	92	0.04	0.36	–
Pakistan	2,026	0.11	0.88	0.09
Philippines	680	0.06	0.63	0.07
Sri Lanka	3,725	1.33	0.80	2.07
Taiwan	374	0.41	0.23	0.23
Thailand	2,256	0.12	0.13	0.16

* Less than 0.01.
Source: Duff. B., IRRI, Philippines, 1978.

Trafficability and Workability of Soils

Proper timing besides available power is closely related to the trafficability and workability of the soil. Water content, water

Fig. 3 Available human, animal and mechanical energy in selected countries

Fig. 4 Potential of soil cultivation with different sources of energy

Fig. 5 Limits of consistency of soil

Fig. 6 Interdependency of energy input and production

suction, rate of evaporation and the gradient of water content related to the depth are decisive for these technological properties of the soil. Many of the soils of semi-arid and arid zones (especially with a high content of fine sand and silt) have only a very limited range of suitable water content (**Fig. 5**). Limits of consistency are general criteria in evaluating soil conditions for tillage.

At high moisture contents (above the lower plastic limit but below saturation where the soil strength is mainly due to the organic bonds, the clods are very weak because of the very low organic matter content of most of the cultivated tropical soils. Thus the clods are very susceptible to deformation and compaction which because of the risk of salination is the basic threat to irrigated soils, especially when tractors and heavy equipment are used. The long-time negative effect is most serious in non-swelling soils because there is no self-correcting effects like in the montmorillonit clay soil.

The lower plastic limit in many cases is at low water contents, especially in alkaline soils. The lower plastic limit is exceeded already even after a small amount of water is available, but after heavy rains (in semi-arid zones), especially in areas of winter rain with low evaporation rates and poorly drained soils, traffic and cultivation are impossible for up to two or three weeks. Also, during and at the end of the rainy season the soils are saturated far beyond the lower plastic limit so that a lot of time is lost until cultivation is possible.

After a narrow zone of water content with optimal workability (often only a few days or even hours due to high evaporation rates) soils with a high content of fine sand and silt become very hard (like concrete up to 20 N/cm^2 of ploughing resistance) and cannot be cultivated by hand or animal. To treat these clod-forming soils with heavy tractors and implements seems to be waste of energy and material.

Increasing Dependency

Besides the attempt to improve the soils by increasing the organic matter content and keeping the soil covered as long as possible two alternatives must be discussed:

– cultivation with high efficiency between shrinkage – and plastic limit of the soil or,

– technical irrigation to keep the water content in between shrinkage and plastic limit during cultivation if water is available.

In both cases besides the necessary tractor, implements, equipment and fuel sufficient know-how and management is needed. The graph of Giles (**Fig. 6**) shows the general increase of production level with power input. Also, Singh and Chancellor, for instance, show that an increased level of mechanization can increase the level of yields considerably but increase also the level of energy input related to the unit of crop. The total costs of production are reduced, the farm income is rising, but the availability and cost of energy will have an increasing influence on highly mechanized production systems.

Facing the general energy situation the idea of maximum input to gain maximum yields typical in irrigation schemes has to be reviewed.

Egypt, for instance, with 100% of irrigated agriculture shows that high yields are also possible with low energy input (0.4 kW/ha, 50% human and animal), at least when water and fertilizer are not limiting factors. Therefore, new approaches have to be investigated. One among these is zero tillage, once started for extensive rainfed agriculture (to prevent erosion) which is tested now, for instance, on irrigated rice in the Philippines. The yields are comperable with those of puddled plots but weed control is still a

problem even with paraquat which is also rare and expensive. Furthermore, water losses are high because there is no water logging layer.

Also, for bed and furrow irrigation, reduced and zero tillage systems were investigated in the USDA SW Great Plans Research Centre. The yields are even higher than with conventional tillage but the management becomes more complicated (the increased amount of plant residue influences water flow and machine operation, herbicide application is more complicated and crop rotation has to be adapted). The tractor energy can be reduced from some 600 to some 200 kWh/ha, but Nebraska experiments, for instance, show that total energy demand can be reduced by only 3% considering the energy to produce herbicides also. So even if the soil seems suitable for direct seeding the following aspects have to be considered:

- availability of herbicides;
- cost of herbicides;
- total energy demand per unit produced;
- appropriate crop rotation; and
- management.

Reduced Tillage ?

Energy as well as time and material can be saved by decreasing the depth of cultivation; intensity, frequency, and accuracy (homogenity and evenness).

The choice of the site and appropriate irrigation system is crucial in soil management in an irrigation scheme as well as the availability of suitable water and the hydrologic aspects.

The internal drainage of excess water is the limiting factor for reduced tillage because any local or general water-logging causes salination and shortage of exygen for the plants. Vertisols or saline and alkaline soils (Na-soils) have a poor internal drainage and are susceptible to compaction so that they need frequent deep and intensive tillage. Sodium, for instance, added with the irrigation water deteriorates the physical soil properties, i.e., the aggregate stability and the plastic limit when pore spaces are reduced. When soil nutrients and irrigation water are inadequate, deeper cultivation can increase and stabilize yields.

Capillary water ascension causing evaporation and salt concentration at the surface has to be reduced, especially when the water table is high. Hardpans, often created during grading, tillage and other field operations have to be broken as well as crusts, often after every irrigation. Accurate cultivation creating well leveled and homogenuous fields can also improve water distribution, save water and allow for bigger plots.

In general, new high yield crops introduced with a new irrigation systems like cotton or sugar beet have an higher claim of deep and intensive cultivation because they are much more sensitive to compaction as traditional rainfed crops. The chance for reducing tillage in irrigated crop production with a high level of yield is very limited.

Because of losses of organic matter and water, the use of the mouldboard plough should be restricted to cases where it is needed for weed control, incorporation of organic matter or lifting of fine material and nutrients. In many cases the tine cultivator or chisel plough has proved sufficient for this purpose.

Plot Size and Accessibility

The general efficiency of field operations and for four-wheel tractors, in particular, is not only a question of power (speed and width of working) but is related to the accessibility, size and shape of field as well as to the distance from farm to field and field to field.

Depending on the irrigation systems, water delivery, slope and leveling of the field and infiltration rate, the plot size is limited. For basin irrigation on sandy loam, for instance, the plot size can exceed 0.5 ha only with a high water delivery rate (> 250 l/s). For strip irrigation the proposed width is between 5 and 20 m only, furrow irrigation, on the contrary, allows furrows up to 500 m long. Farm holdings with a total area of 1 ha only, three or four different crops and scattered fields have plots often not more than 100 m^2. Further, because of the lack of roads, dams and the whole irrigation system (mains and sub-mains as well as drainage canals) the field access with tractors is impossible or at least very time consuming.

Model calculations of Gindele show that working time is increased progressively with decreasing plot size below one ha, especially for large implements, that the most adequate shape of field is rectangular and that the optimal ratio between length and width of field is between 20 and 14 for a one ha plot (500 m furrow length) and 0.1 ha plot (62.5 m furrow length).

For 2,000 m^2 plots the ratio of turning time to working time is excessive. Also, the energy demand is rising with decreasing plot size.

This is why most of the irrigation systems in the developing countries are not suitable for the use of four-wheel tractors. In rice cultivation tractors have to climb over permanent levees or dikes but the other crops, dams and sub-mains often can be removed for tillage of neighbouring plots (even of different owners) and rebuilt before or even after planting.

Data on the suitable ratio between plot size and size of tractor and implement are still inadequate, but it is well known that the total length and manueverability (radius

of turning) are becoming more important as limiting factors for efficients operation in short and small-sized fields.

For small plots mounted implements are preferred and the reversible plow, for instance, has up to 50% more efficiency than a one-way plow besides its good levelling effect. Transport time is decreasing the efficiency considerably. For a 0.5 ha plot,Gindele shows a 2% increase per 100 m of distance between fields i.e., 100% increase for 5 km.

Land consolidation should generally precede farm mechanization. The field layout has to be a compromise between irrigation and mechanization which needs to be considered early in the planing phase for irrigation schemes.

Proper road system is another major problem in the developing countries, especially in old irrigation systems, which were planned for hand operation and animal use.

Summary

Proper timing of soil cultivation is related closely to the available power, especially when the workability of the soils is confined to few days only. The reduction of tillage is limited due to the necessary even distribution and internal drainage of water. The efficient use of tractors is impossible as long as the plots are too small and the access is difficult. Unfortunately, the degree of mechanization of field operations normally is not discussed in the planning phase of irrigation systems.

The main advantages of the use of irrigation water in hot and dry areas are increased production, full-year production, full year employment, full year soil cover (protection), and reduced risk of total loss of harvest due to unfavourable weather. These factors have to be considered when there is increased dependency on technology, energy, management and infrastructure.

To increase production, to minimize production risks and to optimize the total input/output ratio are the main targets for which appropriate soil cultivation can contribute substantially.

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Farm Mechanization Facilities in Hyderabad, Sind Province, Pakistan

by
Kausar Ali Jafri
Atomic Energy Agriculture Research Centre
Tandojam, Sind, Pakistan

Sheruddin Bukhari
Chairman
Department of Farm Power & Machinery
Faculty of Agricultural Engineering & Farm Mechanization
Sind Agriculture University
Tandojam, Sind, Pakistan

Bherulal T. Devrajani
Senior Agricultural Research Engineer and Principal Investigator
Sind Agriculture University
Tandojam, Sind, Pakistan

Introduction

The accelerated growth rate of population and the ever-rising demand for food and fibre make agriculture the most important sector. Agriculture contributes about 35 percent to Pakistan's Gross National Product and absorbs 70 percent of the total population resulting in very low per capital income. The factors responsible for food deficits and poor agriculture involve population explosion, over-emphasis on industrialization, absence of modern production techniques, shortage of essential inputs and lack of production-oriented services for the farmers[1].

One of the important aspects of modern production technology is farm mechanization. Power farming is in no way less beneficial as compared to traditional farming. It has been demonstrated that farm power and machinery give greater economic returns over the conventional methods of cultivation using indigenous implements. Most of the developed countries have attained high living standards due to improved farming methods and mechanized agriculture. Countries like U.S.A. and Japan have horse-power of 0.413 and 0.913 per acre, respectively, as compared to Pakistan's 0.084 in 1975[2]. The suggested horsepower for the effective farming in Pakistan is 0.20 per acre.

Pakistan had only 2,300 wheel tractors in 1958. This quantity increased to 18,000 by 1968 and became appreciable in 1975 when the tractor population reached 40,122. However, the desired goal of horse-power per acre can only be achieved by raising the number of tractors to 250,000 by 1985[3]. Like tractors, tractor-drawn implements have also proved more efficient than bullock-drawn and hand-operated tools. There is always a problem of labour shortage during peak periods and natural hazards cause great damage to crops due to not maintaining timeliness of operations. This, in fact, could be minimized by the introduction of improved tractor-drawn implements.

The small size of farms is the main impediment for farm mechanization as is particularly being felt in Pakistan except in Sind Province where farms are large enough to economically operate farm machines.

To enhance farm mechanization,

1) 'Focus on Agriculture' an article by Dr. Heshamul Haq, Director General, A.R.C, Daily Dawn, Dec. 2, 1977, p.9.

2) Agriculture Statistics of Pakistan, 1975. Government of Pakistan Ministry of Food, Agriculture and Co-operative, pp.56–58.

3) Pakistan Agriculture, by Saeed Hafeez, 1975, pp.13–17.

it is important to analyse all the relevant factors which include availability of farm power and machinery, credit facilities, and training facilities coupled with their proper utilization on farms. The present study is an effort to appraise the mechanization facilities available to farmers or in an area. This ultimately will lead to suggesting better provisions and efficient allocation of the farm mechanization resources. This study was confined to Hyderabad district of Sind Province where the pattern of farm mechanization is more or less typical of the province.

Hyderabad District

Hyderabad district lies between 60°-3' East longitude and between 25°-15' and 26°-6' North latitude. It is located at the lower Indus basin about 98 feet above sea level[4]. The district is divided into four "talukas": Hyderabad, Tando Mohammad Khan, Tando Allahyar and Hala. The district is surrounded by Nawabshah district in the north, Tharparkar in the east, Sanghar in the north-east, Badin in the south-east, Thatta in the south-west and Dadu in the west.

The climate of the district is arid and marine tropical type with low rainfall. Days are hot in summers but nights are comparatively mild. In summer the wind usually blows from south-west to north-east with considerable velocity carrying dust particles. The district being in the influence of the Arabian sea, has a generally humid climate. It has a mean annual rainfall of 3.24 inches varying from 5.62 to 0.86 inches. The mean summer temperature for April-July varies between 103.5°F and 77.0°F and mean winter temperature for December-February fluctuates between 78.1°F and 54.0°F. The highest temperature was recorded in May at 106.6°F with the lowest temperature of 50.7°F in January.

The soils of the district are deep alluvial derived from rocks and deposition of sand and silt by the Indus River with texture of fine sand to clay. Soils in the Tando Mohammad Khan "taluka" are severely affected by salt where underground water is also brakish with T.S.S. ranging from 2,500 to 4,500 ppm. The canal water is the only source of irrigation. The other three "talukas" have better soils carrying sweet underground water, but the main water supply is also through canals.

The Hyderabad district is composed of 2,880 thousand acres of land of which the total cultivated area was 2,228 thousand acres during 1973–'74 including 1,175 thousand acres in fallow and 1,053 thousand acres not sown. The total cropped area during the year was 1,126 thousand acres. However, an area of 652 thousand acres was un-cultivated[5]. The main crops of the district are sugarcane, rice, wheat, cotton, millets, oilseads and legumes.

Method of Study

Hyderabad was selected as the study area for surveying its mechanization facilities, including credit facilities, farm power and machines, other agricultural inputs and the agencies which provide tractors, farm machines, and other necessary requirements for efficient utilization of these facilities. Primary and secondary data were collected for thorough analysis. The survey was undertaken of the tractor dealers, implement dealers, spare parts dealers, implement manufacturers, tractor and implement repair shops, tube-well boring agencies, tube-well spare part dealers, tractor operator training centres, agricultural educational institutions and sugar mills available in the district. This was made possible by personal contacts with the farmers using farm power and machinery. From the list of 39 tractor farms known in the district, only 20 farms were selected for thorough study. Stratified random sampling method was used for selecting the farms. Each "taluka" of the district formed a stratum. Within the stratum five mechanized farms were randomly selected.

Results

Farm mechanization is an important step towards the development of agriculture and national prosperity. Crop yields have increased with the introduction of farm machines. Water and labour scarcity problems are being solved, as in many developed countries, through mechanized farming. Mechanization has also contributed much in developing new lands. Timeliness and optimum requirements of field operations are being successfully gained with the adoption of power farming.

Pakistan is also progressing in the field of farm mechanization with its limited resources. The development in this field is possible after thorough analysis of problems and requirements and providing the solution. Proper utilization of farm power and machinery as well as other facilities determine the pace of machine technology.

4) Agricultural Statistics of Sind, 1975. Bureau of Statistics, Planning and Development Department, Government of Sind, Karachi, p.1.

5) Agricultural Statistics of Sind 1976. Bureau of Statistics, Planning and Development Department, Government of Sind, Karachi, p.11.

Plate 1 Lathes & grinders operating in Central Work Shop, Tandojam

Plate 3 Cross-cut sections of engines and models in a Laboratory of the Faculty of Agricultural Engineering & Farm Mechanization

Plate 2 Agricultural Engineering Workshop, Tandojam

Plate 4 Heavy foundry shop of main workshop

Mechanization Facilities

A satisfactory progress in agriculture is not possible without the investment of huge capital outlay as farm machines are capital extensive. But farmers are generally very poor. Cooperative farming system is lacking which otherwise could solve many problems of the farmers in adopting farm mechanization.

Sugar mills at the Tando Allahyar and Tando Mohammad Khan "talukas" have advanced loans of Rs. 19,416 thousands to 8,206 growers during 1975–76, all loans being seasonal and productive. These loans had been advanced mainly for the purchase of fertilizers and seed and were restricted to sugarcane growers of the mill jurisdiction. The Agricultural Development Bank of Pakistan had also disbursed the developmental loans on short, medium and long terms. The bank advanced Rs. 16,394 thousand to 875 growers mainly for tractors and tube-wells. The role of the United Bank Limited and National Bank of Pakistan was also appreciable as they provided loans of Rs. 3,870 thousand and Rs. 2,014 thousand to 218 and 611 growers, respectively. The Habib Bank Limited, Muslim Commercial Bank Limited, and the Allied Bank Limited also loaned Rs. 661 thousand, 562 thousand, and 215 thousand to 69, 61, and 25 growers, respectively.

The revenue department in the district provided developmental loans and productive loans of Rs. 222 thousand to only 28 growers. The co-operative societies provided loans of Rs. 293 thousand to 82 growers. The "taluka" credit data show that different agencies at the Tando Allahyar and Tando Mohammad Khan provided higher amounts of loans to greater number of growers than Hyderabad and Hala. The Co-operative Societies provided credit only in the Tando Allahyar 'taluka."

Of the 465 wheel-type tractors in the district, 440 were privately owned and 25 were public owned. The latter tractors are managed by the Agricultural Engineering Workshops and are rented to farmers.

Plate 5 Chain type tractor engine repairs in Agricultural Engineering Workshop, Tandojam

Plate 7 Traditional bullock-drawn implements & hand tools for demonstration at Sind Agricultural University, Tandojam

Plate 6 Farm machines lying scattered in the sun and under trees (General conditions)

Plate 8 Tractor repair and overhaul workshop

The privately-owned 440 tractors, on the other hand, were distributed as follows: 145 in Hala, 134 in Tando Allahyar, 99 in Hyderabad, and 62 in Tando Mohammad Khan. In addition, 60 chain-type tractors were made available in the district by the government for rent to farmers for land development. Six tractor dealers and nine general agricultural machinery dealers (all private) operated in the district. Spare parts were provided by 20 spare-part dealers (2 public and 18 private); 10 in Hyderabad, 6 in Tando Allahyar and 4 in Tando Mohammad Khan. Also, 17 tractor-drawn implement manufacturers (all private), operated in the district; 15 in Hyderabad and one each in Tando Allahyar and Tando Mohammad Khan.

The district had 27 tractor repair workshops (2 public and 25 private) for major tractor repairs, and 53 agricultural machinery repair shops (2 public and 51 private). Besides several other small shops also provided minor tractor and implement repair facilities in the interior of the district.

The facility of 20 tube-well boring agencies (2 public and 18 private) and 28 tube-well repair and spare part dealers (2 public and 26 private) had also supplemented the mechanization facilities. The Sind Agriculture University, Tandojam has been imparting education in different fields of agriculture. Tractor-operator training facilities were also provided by two training centres at Tandojam. There were also 2 sugar mills, 29 cotton factories, 8 agricultural extension centres and 85 co-operative societies in the district. In spite of the availability of these facilities more credit is needed to finance new workshops, repair shops, training centres and farm power and farm machines as well as roads. Ferguson (1961) suggested roads, education, training, repair facilities as the measures in support of farm mechanization.

The horsepower availability in the district averaged 0.2767 per acre. About three-fourths of available tractors were of the 55 hp range. The rest were either 45 hp, 62 hp or 95 hp ranges.

Tractor availability notwithstanding, a considerable number of bullocks were still in use in many farms. The 594 bullocks in the district a total of 198.01 hp, distributing an average of 0.017 hp power per acre on tractor farms or an average of 0.284 hp/acre for the entire district. Devrajani (1977) estimated a very low horsepower of 0.08 per acre for Hyderabad district on traditional farms.

On some tractor farms, oil engines, electric generators and motors were also available. Ten oil engines comprising a total of 240 hp and 13 electric motors were used to operate tube-wells and to generate electricity for domestic purposes. There were two small portable generators of 3.5 KW each on two farms supplying limited light to residences.

Of the 20 tractor farms, 16 used 27 disc plows, 14 used 19 mould board plows, 5 used 6 rotavators, 14 used 17 ridgers, 18 used 30 tractor blades, 2 used land scrapers, 8 used 9 border disc, 11 used 12 wheat drills, 8 used 10 cotton planters, 2 used cane-planters, 2 used 2 self-propelled combines, 2 used power-take-off combines, 12 used 12 wheat threshers, 10 used 13 power sprayers and all of the farms used 37 tandem disc harrows, 31 cultivators and 25 trailers. The machine inventory indicates that a majority of these growers possessed tillage machines needed for plowing, levelling, interculturing, ridging and bund making. The use of sowing machines like wheat drills and cotton drills were to the extent of 55 percent and 40 percent, respectively: whereas, cane planters were only 10 percent on the studied mechanized farms. Four mechanized farms had two self-propelled and two tractor-drawn combine harvesters.

The use of levellers, cultivators, tandem disc harrows and trailers was observed in the district which was also reported by Milik (1974) on 30 tractor farms in the same district. This was again in conformity with Channar (1974) for Nawabahah district of Sind. It was further reported by Devrajani (1977) on 50 progressive farms that disc plows, cultivators, blades and tandem disc harrows were commonly used and widely accepted in Sind province. The bullock implements were also available. The main use of bullock drawn implements was in the share cropping system.

The 5 tables that follow summarize the distribution of available farm machineries and services in the district.

Table 1. Distribution of Credit Facilities in Hyderabad District, 1975–76

(000 Rupees)

Agencies	"Taluka"				Total
	Hyderabad	T.A. Yar	T.N. Khan	Hala	
Sugar mills	–	9,416 (3,706)	10,000 (4,500)	–	19,416 (8,206)
Banks					
Agricultural Development Bank of Pakistan	3,465 (175)	5,194 (212)	5,011 (293)	2,724 (195)	16,394 (875)
United Bank Limited	987 (35)	1,003 (50)	1,250 (109)	630 (24)	3,870 (218)
National Bank of Pakistan	49 (13)	848 (268)	600 (300)	517 (30)	2,014 (611)
Habib Bank Limited	257 (22)	54 (6)	–	350 (41)	661 (69)
Muslim Commercial Bank Limited	99 (11)	232 (29)	81 (6)	150 (15)	562 (61)
Allied Bank Limited	149 (16)	40 (5)	26 (4)	–	215 (25)
Co-operative Societies	–	293 (82)	–	–	293 (82)
"Taccavies"	119 (14)	56 (9)	32 (3)	15 (2)	222 (28)
Total	5,125 (286)	17,136 (4,367)	17,000 (5,215)	4,386 (307)	43,647 (10,175)

Note: Figures in parenthesis refer to number of farmers.

Table 2. Distribution of Farm Mechanization Facilities in Hyderabad, 1975–76

(Unit: Number)

Description	Hyderabad	T.A. Yar	T.N. Khan	Hala	Total
Wheel-type tractors	99	134	62	145	440
Buldozers	–	–	–	–	60
Tractor dealers	6	–	–	–	6
Tractor repair workshops	16	5	6	–	27
Implement dealers	9	–	–	–	9
Implement manufactures	15	1	1	–	17
Implement repair workshops	28	12	11	2	53
Tractor spare-part dealers	10	6	4	–	20
Tubewell boring agencies	15	1	–	4	20
Tubewell repair and spare dealers	20	2	–	6	28
Sugar mills	–	1	1	–	2
Cotton factories	13	9	–	7	29
Agricultural extension centres	5	1	1	1	8
Co-operative societies	14	37	10	24	85

Sources: Office of the Extra Assistant Director of Agriculture, Excise and Texation and Food Department, Hyderabad, including personal contacts.

Table 3. Public and Private Farm Mechanization Facilities in Hyderabad, 1975–76

(Unit: Number)

Facility	Public	Private	Total
Wheel-type tractors	25	440	465
Buldozers	60	–	60
Tractor dealer	–	6	6
Tractor spare-part dealers	2	18	20
Implement dealers	–	9	9
Implement manufacturers	–	17	17
Tractor repair workshops	2	25	27
Implement repair workshops	2	51	53
Tubewell boring agencies	2	18	20
Tubewell repair and spare-parts dealers	2	26	28
Training centres	2	–	2
Education centres	1	–	1

Sources: Office of the Deputy Director of Agriculture and Extra Assistant Director of Agriculture, Hyderabad, including personal contacts.

Table 4. Farm Power Available in Selected Mechanized Farms, Hyderabad, 1975–76

Farm No.	Tractors Available		Farms Area (Acres)	Horse-power/Acre
	No.	H.P.		
1	3	245	700	0.3500
2	2	100	105	0.9524
3	2	110	300	0.3667
4	2	117	380	0.3078
5	2	110	142	0.7746
6	6	330	900	0.3666
7	4	220	800	0.2750
8	3	179	450	0.3977
9	2	110	280	0.3928
10	3	165	650	0.2538
11	3	186	1,600	0.2537
	4	220		
12	4	210	800	0.2625
13	2	110	540	0.2037
14	3	165	1,000	0.1650
15	2	100	600	0.1666
16	2	110	450	0.2444
17	2	100	375	0.2666
18	2	100	575	0.1739
19	3	172	700	0.2457
20	1	64	300	0.2133
Total or Average	57	3223	15,647	0.2767

Table 5. Bullock Horse-Power Available in Selected Mechanized Farms, Hyderabad, 1975–76

Farm	Farm Size (acres)	Number of Bullocks	Total Hp Equipment	Average Hp Equipment/ha
		Tractor Farms		
1	700	–	–	–
2	105	–	–	–
3	300	24	8.00	0.026
4	380	38	12.67	0.033
5	142	14	4.67	0.033
6	900	–	–	–
7	800	74	24.67	0.031
8	450	–	–	–
9	280	28	9.33	0.033
10	650	–	–	–
11	1,600	–	–	–
12	800	60	20.00	0.025
13	540	50	16.67	0.031
14	1,100	90	30.00	0.030
15	600	50	16.67	0.028
16	450	46	15.33	0.034
17	375	36	12.00	0.032
18	575	56	18.67	0.032
19	700	–	–	–
20	300	28	9.35	0.031
Total or Average	11,647	594	198.01	0.017
		Traditional Farms		
1	65	10	3.33	0.051
2	74	12	4.00	0.054
3	37	6	2.00	0.054
4	81	14	4.67	0.058
5	32	6	2.00	0.062
6	47	8	2.67	0.056
7	39	6	2.00	0.051
8	73	12	4.00	0.054
Total or Average	448	74	24.67	0.055

Source: Devrajani, B.T., Efficacy of Various Machines Towards Increased Agricultural Production in Sind Province of Pakistan, Final Report Phase-I. (Sind Agriculture University, Tandojam, 1977.) ■■

Hand Tractors Manufactured in the Philippines

by
Roberto C. Bautista
Director

Eugenio C. Castro, Jr.
Agricultural Engineer

Agricultural Machinery Testing and Evaluation Center (AMTEC), University of the Philippines
Los Baños, College, Laguna, Philippines, 3720.

Introduction

Several types of hand tractors are currently used in the Philippines. They are either locally manufactured or imported and are generally suitable for the medium- and small-sized farms. These hand tractors are identified as pedestrian, garden, walking, single-axle, two-wheeled and power tillers.

Foreign-made hand tractors were introduced in the country more than 20 years ago. For several years they dominated the local market sales. The initial manufacture and development of locally manufactured hand tractors in the Philippines started in small scale in 1966. It accelerated in the years that followed.

By mid-1979, there were more than 65 fabricators of hand tractors in the country. All of them, however, utilized imported engines as prime mover. Some of them, however, suspended the production of hand tractors. Hand tractors are designed either with tractive axle drive located in front of the engine or mid-way of the main body. Their design and development of various components are continually being improved for higher efficiency and better adaptability to Philippine farm conditions. (Refer to **Figs. 1** to **4**)

*Acknowledgement – Heartfelt gratitude is extended to the various companies who supplied brochures and to those who provided verbal information on their hand tractors; Dr. Jun Sakai for helpful suggestions in improving the format of this paper; to Dr. Reynaldo M. Lantin for the editing work; to Mr. Oscar C. Gatdula for the preparation of illustrations; and to Miss Rosario A. Hernandez for typing work.

Classification of Hand Tractors

These hand tractors or power tillers have been classified into three types (Orcino 1974) as single-axle, general, and double-

Fig. 1 Mid-section location of power drive type pedestrian tractor

Fig. 2 Front drive type pedestrian tractor

Table. 1 Annual Hand Tractors Sales and Portion of Sales Financed Through CB-IBRD Program, 1967–78.

Year	Total Units Sold	Units Financed Through CB-IBRD	Percent of Total Sales
1967	3,508	724	24
1968	1,873	228	12
1969	910	34	4
1970	475	42	9
1971	680	109	16
1972	1,408	330	23
1973	3,120	322	10
1974	6,721	377	6
1975	11,077	805	7
1976	9,352	–	–
1977	7,853	–	–
1978	7,803	–	–

* Central Bank of the Philippines–International Bank for Reconstraction and Development Loan Program.

Source: Juarez F. and B. Duff. Changing Supply and Demand Patterns for Power Tillers in the Philippines. Philippine Society of Agricultural Engineers (PSAE), 1977, The Economic Monitor, August 29, 1977, AMMDA Report, 1977, and Agricultural Engineers Yearbook, 1979, PSAE.

Fig. 3 Rotary plow of a mid-section location of power drive pedestrian tractor (in place of the cage wheel)

Fig. 4 Comb-tooth harrow for a pedestrian tractor

axle power tillers.

Single-axle Power Tillers

These power tillers are lightweight, usually with 4 to 6 hp gasoline engines. Rotary tiller blades are mounted on a transverse main axle which are directly driven by the engine through chain and sprocket.

They can often be equipped with pneumatic tires for dryland work or haulage. There is neither a differential mechanism in the axle nor a steering clutch.

General Power Tillers

These types are usually equipped with engines of up to 8 hp. They have wheels and can perform several farm operations by attaching conventional draft-dependent farm implements such as plows, harrows, and cultivators. Tillers of this type have steering clutch, reverse drive, and multi-speed shifting transmission.

Double-axle Power Tillers

These types have two driven wheels, and the tilling mechanism consists of a series of knives attached to a rotating shaft installed behind the main wheel axle. Although these tillers are not as versatile as the other two types, they are well suited to tilling heavy clay paddy fields because of their sturdier construction and larger engine. Generally, these tractors are equipped with diesel engines of 6 to 14 hp.

Hand Tractor Sales

Available data on tractor sales in the country for a 12-year period (1967–1978) show a mixed pattern of ups and downs. **Table 1** indicates that sales of 3,058 units in 1967 plunged to only 475 units four years later but picked up gradually in the four years that followed reaching a peak of more than 11,000 units in 1975. From thereon, sales slowed down again to 7,803 units in 1978.

This sales phenomenon cannot

be easily explained by known factors except to speculate on the effective or ineffective promotion by the manufacturers or the government of the use of these farm machines. Even the loan subsidy made available by the World Bank through the Central Bank of the country did not seem to have any material impact on the sale and manufacture of these power tillers.

Gasoline-type tillers are still more popular than diesel types **(Table 2)** and locally manufactured hand tractors command a growing share of the domestic market **(Table 3)**.

The future of the hand tractor industry in the Philippines seems to be in a delicate balance as indications seem to show that its growth or stagnation will be influenced by the quality and price that the many manufacturers are assembling and selling. To date, 45 manufacturers, mostly small in scale, are in the business and one wonders if this many is warranted in the face stiff competition and dwindling sales. **Appendix I** lists the name, address and brands manufactured.

Table 2. Sale of Hand Tractors by Fuel Type 1974–78

Year	1974		1975		1976		1977		1978	
	No.	%	No.	%	No.	%	No.	%	No.	%
Gasoline	3,219	48	6,968	63	6,878	74	6,152	78	6,200	79
Diesel	3,502	52	4,109	37	2,474	26	1,701	22	1,603	21
Total	6,721	100	11,077	100	9,352	100	7,853	100	7,803	100

(Same Sources Cited in Table 1)

Table 3. Sale of Hand Tractors by Source 1974–78

Year	1974		1975		1976		1977		1978	
	No.	%	No.	%	No.	%	No.	%	No.	%
Local	2,338	35	5,225	47	5,670	61	5,136	65	6,227	80
Imported	4,383	65	5,852	53	3,682	39	2,717	35	1,576	20
Total	6,721	100	11,077	100	9,352	100	7,853	100	7,803	100

(Same Sources Cited in Table 1)

Features and Specifications of Hand Tractors

Listed below are the features and specifications of hand factors made available by the manufacturers/distributors either through brochures or interviewers. As such, the AMTEC which has yet to conduct tests and evaluations of these machines, maintains neutrality in printing the specifications here without suggesting that other brands not listed here (due to unavailability) are in anyway inferior.

1. **Aquabug Hand Tractor** (Manufactured by Victorias Agro-Industrial Corporation)

a. Plows at least 1.5 ha per day.
b. Cultivates and cleans edges of field or dikes.
c. Floats in deep mud.
d. Weeds and rice stubbles can be shredded and thoroughly incorporated in puddled soil.
e. Utilizes chain drive which provides positive action.
f. Employs only one lever to regulate both engine and rotavating speeds.
g. Throws mud forward in contrast with other power tillers.
h. Equipped with centrifugal clutch mechanism which automatically disengages power drive during idling and starting.
i. Energy and power losses are minimal due to heavy traction wheel, no belt drive slippage, and automatically starts puddling soil as soon as engine speed is increased.
j. Engine is removable for other uses like operating irrigation pumps, threshers, generators, etc.
k. Other specifications are:
Length . . . . . 150 cm.
Width . . . . . 100 cm.
Thickness of body . . 22 cm.
Weight . . . . . 200 kg.
Puddle wheel operating speed
. . .380 RPM to 450 RPM
Fuel consumption
. . .17 liters gasoline/ha
Prime mover
. . .16 hp Briggs and Stratton
Drive. . . . . .Located in front of body

2. **Turtle Brand Tractor** (Manufactured by SV Agro-Industries Enterprises, Inc.)

a. Plows at least 1.5 ha per 8-hours.
b. Floats in mud.
c. Cultivates and cleans edge of the field or dike.
d. Weeds and rice stubbles can be shredded and thoroughly incorporated in the puddled soil.
e. Uses a belt tension type clutch mechanism.
f. Engine is removable for other uses like operating irrigation pumps, threshers, generators, etc.
g. Performs plowing, mowing rotavating and leveling in one operation.
h. It can be used in fishponds due to its ability to float.
i. Other specifications are:
Length . . . . 140 cm.
Width . . . . . 111 cm.
Fuel consumption
. . 8 li. gasoline/8 hr.
. . 4 li. diesel/8 hr.
Prime mover
. . 12-16 hp gasoline engine
. . 10-11 hp light weight diesel engine like Ducati or Lombardini
Front drive

3. **Adriatica Hand Tractor** (Distributed by Agroplex International, Inc.)

a. Powered either by a .8-14 hp. gasoline or diesel engine.

b. Uses belt-tension type clutch mechanism.
c. Tractor speed can be varied by combination of pulley and V-belt.
d. Carries attachments such as pneumatic tires, rotavator, furrower, puddling wheel and mouldboard plow.

4. **Alpha Hand Tractor** (Manufactured by Alpha Machinery and Engineering Corporation)

a. Equipped with pivot controls for turning operation.
b. Constructed with chain case (sealed bearings) and heavy duty main gear housing and chassis.
c. A detachable rotary tiller assembly is equipped with center blade mechanism for tilling operation.
d. A belt tension type with over drive is used as clutch mechanism which disengages the engine drive from machine.
e. Carries implements and attachments such as rotary tiller assembly with two speed transmissions and 13 pieces of blades, raking steel wheel assembly, and single mouldboard made of high carbon steel.
f. Other specifications are:
   Weight. . . . . 170 kg.
   Tillage width . . . . . 45.7 cm.
   Prime mover
   . . .11 bhp/200 rpm SLANZI DVA-460

5. **Anos Hand Tractor** (Manufactured by Anos Research)

a. Main clutch is of multiple disc type which is enclosed for waterproof operation.
b. Provided with specially designed side clutch for ease of turning.
c. Transmission is housed in cast aluminum, provided with gear and sprocket reduction unit merged in oil, double axle type and of mudproof construction.
d. Powered by 7.0 Hp gasoline engine.
e. Operating handle can be adjusted up or down.
f. Useful for plowing, tilling, seeding, ridging, weeding fertilizing, trailer transport, pumping and spraying.

6. **BM Hand Tractor** (Manufactured by Bicol Master Industries)

a. Heavy duty designed machine with balanced body, no vibrations and parts are made of standard sizes.
b. Carries attachments and implements such as puddling wheel, spiral plow, set of harrows, lug wheel, single plow, trailer and pneumatic tires.

7. **Banaue Hand Tractor** (Manufactured by Western Shiroishi Manufacturing Corporation)

a. Powered by a 10-hp gasoline engine.
b. Transmission gear system consists of 4 forward and 2 reverse speeds.
c. Capacity is as follows:
   Rotavator . . 8 to 15 hrs/ha.
   Rake. . . . . 4 to 6 hrs/ha.
   Plow. . . . . 8 to 13 hrs/ha.
d. Weighs . . . . . 195 kgs.

8. **Buffalo Hand Tractor** (Manufactured by Farm Equipment Industries)

a. Light weight and its has well-balanced design and adjustable handle for ease and comfort in operation.
b. Uses a belt tension type clutch mechanism with belt idler positioned inside the belt for long belt life service.
c. Carries attachments such as puddy wheels, harrows, trailer, spiral plow and pneumatic tires.
d. Powered by either 7 – 12 hp. gasoline or diesel engine.

9. **Carabao Hand Tractor** (Manufactured by Iloilo Repair Shop)

a. Equipped with cage wheel which operates independently and two plates to carry unit even at knee-deep muddy soil.
b. Powered by a 6 hp diesel engine (Lombardini).
c. Provided with a multi-speed transmission system.
d. Carries attachments as cage wheel, rotavator and spiral plow.

10. **Ciron Hand Tractor** (Manufactured by Von Machinery)

a. Harrows and cleans ricefield simultaneously.
b. Equipped with clutch pulley and power loss is minimum due to less belt slippage.
c. Plows 1 ha/8 hr.
d. Carries attachments and implements such as mouldboard plow, spiral plow, puddling wheels leveling rake, steel lug wheels, pneumatic tires, trailer and harrow.

11. **Farm Master Hand Tractor** (Manufactured by Isarog Industries)

a. Powered by an 8 hp, 4 cycle gasoline engine (Briggs and Stratton or Honda).
b. Provided with multi-speed transmission system consisting of chains and sprockets.
c. Carries attachments such as cage wheels, peg-tooth harrow and spiral plow.
d. Other specifications are:
   Overall length . . . 226.0 cm.
   Overall width . . . . 136.5 cm.
   Height . . . . . 82.5 cm.
   Gross weight with cage wheels and harrow . . . . . 120 kg.

12. **Filipinas Hand Tractor** (Manufactured by Filipinas Electro-Industrial Corporation)

a. Low center of gravity to prevent overturning.
b. Performs plowing, harrowing, tilling cultivation and hauling.
c. Adjustable handle bar to suit need of tractor operator.
d. Utilizes belt-tension type clutch system.

13. **Hercules MB 11 Hand Tractor** (Manufactured by Malinta Metal, Inc.)

a. Equipped with planetary gear

system steering clutch.
b. Employs power clutch/pulley which uses a jeep clutch-disc-pulley system.
c. Wide travelling speed range and takes V-pulley drives from 4.5 to 8 inches giving a linear speed at no tire slippage from 4.01 kph to 10.69 kph at 2,400 to 3,600 engine's RPM.
d. Adjustable handle bar to conform with need of operator.

14. **"Lakas Elepante" Hand Tractor** (Manufactured by P.I. Industrial Manufacturing and Machine Shop, Inc.)

a. Powered by Briggs and Stratton 7-17 hp gasoline.
b. Carries attachments such as spiral plow, roller, puddling wheels, upland cage wheel, mouldboard plow, disc-plow, and trailer.
c. Operates irrigation pump and generator.
d. Works on wet and dry fields.

15. **"Lakas Kuliglig" Hand Tractor** (Manufactured by P.I. Farm Product, Inc.)

a. Operated with lever at end of right handle which engages main drive (belt-tension type) and a lever at end of left handle as its accelerator.
b. Low center of gravity and its power – weight ratio gives provides greater more power for various work.
c. Equipped with chain tightener.

16. **"Limbas" Hand Tractor** (Manufactured by Nibros Machinery Corporation)

a. Uses tapered cage wheels for ease of turning.
b. Carries attachments such as roller, spiral plow, mouldboard plow, harrow, twin disc plow and rotavator wheel.
c. Overall length . . . 215.9 cm.
Overall width . . . . 111.7 cm.
Height . . . . . 106.7 cm.
Weight w/o engine. . .104.0 kg.

17. **Magico Hand Tractor** (Manufactured by Machinery for Agriculture and General Industries Company, Inc.)

a. Can be installed with either gasoline or diesel engine designed with minimum vibration resulting in less operator fatigue.
b. Equipped with pivot control for steering, cornering and maneuverability.
c. Carries attachments and implements such as mouldboard plow, pneumatic tires, trailer, cage wheel and harrow.
d. Other specifications are:
Prime mover
. . .8-10 hp Briggs and Stratton (gasoline)
. . .7 hp Ducatti or Lombardini (diesel)
Capacity (area plowed)
. . .1 ha/10 hr.
Main clutch . .Belt tension type

18. **Oberly Super "Kalabaw" Hand Tractor** (Manufactured by Oberly and Company Inc.)

a. Powered by a 8-10 hp 4-stroke gasoline engine.
b. Carries attachments such as mouldboard plow, cage wheel and peg-tooth harrow.

19. **Philand Hand Tractor** (Manufactured by Philand Machineries)

a. Utilizes a 10 hp MAG kerosene engine or 8-11 Hp Intermotor engine.
b. Carries attachments such as paddy cage wheels, peg-tooth harrow, spiral plow and disc plow.
c. Plows 1 ha/8 hrs.

20. **R S Hand Tractor** (Distributed by Mayon Equipment Marketing Corporation)

a. Utilizes a hexagonal tractive drive shaft cross section.
b. Uses plunger type clutch system for longer belt life.
c. Powered by a 7-16 hp, 4-stroke gasoline engine.
d. Carries attachments such as spiral plow, cultivators, mouldboard plow and rotavator.
e. Overall length . . . 184.0 cm.
Overall width . . . . . 58.5 cm.
Weight w/o engine . 59.0 kg.

21. **"Sagisag" Hand Tractor** (Distributed by Tramat Mercantile Inc.)

a. Utilizes jeep clutch disc.
b. Handle bar can be adjusted to suit tractor operation position.
c. Axle is made of hexagonal cross-section.
d. Other specifications are:
Tilling width with spiral plow
. . . . . 155 cm.
Overall length . . . . . 190 cm.
Overall width . . . . . 140 cm.
Weight. . . . . 110 kg.

22. **SM Hand Tractor** (Manufactured by SM Industries Co.)

a. Operates with a single lever located at left hand side of handle bar which controls tension of the V-belt (belt tension type of clutch mechanism).
b. Carries attachments are:
a. Rotary plow – Total width covered: 114 cm. Maximun depth of cut: 10.12 cm.
b. Cage wheel – Functions as rotavator which crushes the soil into mud form.
c. Harrow – Especially designed to make leveling easy and simple.
c. Other specifications are:
Length . . . . . 172 cm.
Width . . . . . 114 cm.
Weight. . . . . 125 kg.
Tilling width. . . . . 114 cm.
Capacity (area plowed) 1 ha/day
Prime mover
7-10 hp Briggs and Stratton
Main clutch . . Belt tension type

23. **Springfield Hand Tractor** (Manufactured by Springfield Industries)

a. Performs plowing, puddling, cultivating and hauling.
b. Uses double belt tension type clutch mechanism.

c. Tractor speed can be altered by changing pulley size.

d. Carries attachments such as mouldboard plow, spike-tooth harrow, puddle wheel, spiral plow and pneumatic tires.

e. Other specifications are:

Overall length . . . . . 193 cm.
Overall width . . . . . 113 cm.
Height . . . . . 87 cm.
Weight w/o engine . . . 130 kg.
Plowing capacity
Dry land . . . . . 0.5 ha/9 hrs.
Irrigated lowland paddy
. . . . . 2.0 ha/10 hrs.

24. "Tamaraw" Hand Tractor (Manufactured by Schmid and Oberly Inc.)

a. Operates on belt-tension type of clutch system.

b. Has a two forward adjustable speeds for transport and various field operations.

c. All-steel construction with hexagonal axle provided with heavy duty ball bearings.

d. Carries implements and attachments such as cage wheels, mouldboard plow, comb harrow, spiral plow, pneumatic tires and trailer.

25. Warner Barnes Hand Tractor (Manufactured by Warner Barnes Co.)

a. Powered by 8-hp Briggs and Stratton gasoline engine.

b. Handle bar can be adjusted at most convenient position of operator.

c. Carries attachments such as cage wheel, mouldboard plow, rotavator, pneumatic tires, spike-tooth harrow and spiral plow.

d. Other specifications are:

Overall weight. . . . 91 kg.
Length . . . . . 220 cm.
Width . . . . . 109.2 cm.
Height. . . . . 90 cm.

26. Wilcon Hand Tractor (Manufactured by Wilcon Machinery and Equipment)

a. Powered by 7-16 hp Briggs or Stratton gasoline engine.

b. Uses belt tension type clutch mechanism with belt idler positioned inside belt.

c. Carries rotary plow, cage wheel and harrow.

Summary

There are 65 known hand tractors manufactured in the Philippines which commands a growing share of the domestic market.

The major features of these hand tractors are:

a. Preponderance of single-speed transmission system.

b. Use of imported engines as prime mover, either gasoline, kerosene or diesel ranging from 5 to 16 hp.

c. There are two locations of power transmission; one at mid-section of the tractor and in front of the engine.

d. The common attachments or implements are: spiral plow, mouldboard plow, puddling wheels and peg-tooth harrow.

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APPENDIX I: Philippine Hand Tractor Brands and Address of Manufacturers/Distributors

Brand	Manufacturer/Distributor
1. A-B	FARM INCORPORATED A. de Guzman Street Bo. Concepcion, Marikina Metro Manila
2. ABANDO	ABANDO METAL SHOP Sto. Tomas La Union
3. ADRIATICA* a. Lince b. Pantera c. Tigre	AGROPLEX INTERNATIONAL INCORPORATION 1195 Pasong Tamo, Makati Metro Manila
4. AETNA	AETNA STEEL INDUSTRIES INCORPORATION Km 16 South Super Highway, parañaque Metro Manila
5. ANOS*	ANOS RESEARCH 6 Anak Bayan Street San Francisco del Monte Quezon City
6. ALANETE	AGRIMASS MARKETING CORPORATION Suite 410 Victoria Building 11th Avenue, Grace Park Calooan City
7. ALPHA*	ALPHA MACHINERY AND ENGINEERING CORPORATION 1167 Pasong Tamo, Makati Metro Manila
8. AQUABUG*	VICTORIAS AGRO-INDUSTRIAL CORPORATION Vicmico, Victorias Negros Occidental

9.	AQUINO	AQUINO HAND TRACTOR Palo, Leyte
10.	BANAUE*	WESTERN SHIROISHI MANUFACTURING CORPORATION 433 Regina Building Escolta, Manila
11.	BM*	BICOL MASTER INDUSTRIES San Dinaga, Caramoan Camarines Sur
12.	BUFFALO*	FARM EQUIPMENT INDUSTRY 72 San Felipe Naga City
13.	BTW-S	FREEPORT SHIPYARD AND ENGINEERING CORPORATION 1728 Jose Abad Santos Avenue Metro Manila
14.	CARABAO*	ILOILO REPAIR SHOP 69 Fuentes Street Iloilo City
15.	CIRON*	VON MACHINERY Anayan, Pili Camarines Norte
16.	DUHAY-LUNGSOD	DUHAY-LUNGSOD MACHINERY SHOP Castillo Street Davao City
17.	DURASTEEL	DURASTEEL INCORPORATION Cainta, Metro Manila
18.	EL TORO	SEA COMMERCIAL COMPANY INCORPORATION 3085 Ramon Magsaysay Boulevard Sta. Mesa, Metro Manila
19.	FARM-MATE	COMMODITY MARKETING CENTER OF ASIA INCORPORATION 3rd Floor, FCA Building, Aguirre Street, Legaspi Village, Makati Metro Manila
20.	FARM MASTER*	ISAROG INDUSTRIES 826 Renacimiento Street Naga City
21.	FARMACOR*	FARM MACHINERY COMPANY Aurora Blvd., cor., Andrews Street Pasay City, Metro Manila (Distributor only for the hand tractor)
22.	FIELD MASTER* (Model to be replaced by a new one)	MARSTEEL CORPORATION 839 E. de los Santos Avenue Quezon City
23.	FILIPINAS*	FILIPINAS ELECTRO-INDUSTRIAL 341 McArthur Highway, Malinta Valenzuela, Bulacan
24.	FIMCO	FARM IMPLEMENTS MARKETING CORPORATION 12th Avenue, Grace Park Caloocan City
25.	HERCULES MB 11*	MALINTA METAL INCORPORATION 314 McArthur Highway, Malinta Valenzuela, Bulacan
26.	IGRI	IGRI INDUSTRIAL SALES CORPORATION 484 G. Araneta Avenue Quezon City
27.	JINIL	NIBROS MACHINERY CORPORATION Doña Rosarip Jeogjts. Mpvaôcjes Quezon City
28.	J L	M. VEJON EQUIPMENT Mayon Street Naga City
29.	JB	JESUS BALISTA Jaro, Iloilo City
30.	KAUNLARAN	KAUNILARAN INDUSTRIES INCORPORATION Calamba, Laguna
31.	LAKAS AGILA	ADRIANO METAL GRAFT INCORPORATION 6-A McArthur Highway, Marulas Valenzuela, Bulacan
32.	LAKAS ELEPANTE*	P.I. INDUSTRIAL MANUFACTURING MACHINE SHOP INCORPORATION 235 E. McArthur Highway Valenzuela, Bulacan
33.	LAKAS KULIGLIG*	P.I. FARM PRODUCTS INCORPORATION Km 16 Malanday Valenzuela, Bulacan
34.	LIMBAS*	NIBROS MACHINERY CORPORATION Doña Rosario Heights, Novaliches Quezon City
35.	LOVSTED	LOVSTED AND COMPANY INCORPORATION Km 13 South Super Highway Smith Bell Compound Parañaque, Metro Manila
36.	MADECO	IB MARKETING Elias Street, Naga City
37.	MAGICO*	MACHINERY FOR AGRICULTURAL AND GENERAL INDUSTRIES COMPANY INCORPORATION 200 Liboton Street Naga City
38.	MARSTEEL* (Model to be replaced by a new one	MARSTEEL CORPORATION 839 E. de Los Santos Avenue Quezon City
39.	OBERLY (SUPER KALABAW)*	OBERLY AND COMPNAY INCORPORATION 253 Mayon Street, Sta. Mesa Heights Quezon City
40.	PANG-ARARO 100	ERICMAR ENTERPRISES INCORPORATION Agro-Industrial Division No. 11 Putatan, National Highway Muntinlupa, Metro Manila
41.	PHILAND*	PHILAND MACHINERIES Philand Building Javier Street cor., Pasong Tamo, Makati, Metro Manila
42.	POLYGON	POLYGON AGRO-INDUSTRIAL CORPORATION 1197 E. de los Santos Avenue Quezon City
43.	P P E	P. PEÑA ENTERPRISES Old San Roque Street Pili, Camarines Sur
44.	R G	MASCOT AGRO-INDUSTRAIL SUPPLY CORPORATION 52 Elias Angeles Street Naga City
45.	R S*	MAYON EQUIPMENT MARKETING CORPORATION Taal Avenue, Monterey Village Naga City
46.	ROBIN	GAYEM CORPORATION 1141 E. de los Santos Avenue Quezon City
47.	SAGISAG*	TRAMAT MERCANTILE INCORPORATED 98-BP Santiago, Valenzuela Bulacan

48. S M* — SM INDUSTRIES COMPANY
San Andres Subdivision
Liboton Interior, Naga City

49. SEPARA — SEPARA HAND TRACTOR
Real Street, Tacloban City
Leyte

50. STALLION — MAKATI MACHINERY AND EQUIPMENT COMPANY INCORPORATION
1142 President E. Quirino
Paco, Manila

51. SPRINGFIELD* — SPRINGFIELD INDUSTRIES
J.P. Cabaguio Avenue
Davao City

52. TAMARAW* — SCHMID AND OBERLY INCORPORATION
39 Buendia Avenue
Makati, Metro Manila

53. TURTLE* — S.V. AGRO-INDUSTRIES ENTERPRISES, INC.
65 Commission Civil
Jaro, Iloilo City

54. VARONA — VARONA HAND TRACTOR
Real Street
Tacloban City
Leyte

55. W. B.* — WARNER BARNES AND COMPANY INCORPORATION
2900 Faraday Street cor., South Super Highway, Makati, Metro Manila

56. WILCON* — WILCON MACHINERY AND EQUIPMENT
1081-1020 C. M. Recto Avenue
Manila

57. – ARAGON METAL INDUSTRIES
Tacloban City

58. – ARBOLEDA ENGINEERING ENTERPRISES
1343 E. de los Santos Avenue
Quezon City

59. – CARVIC FARM MACHINERIES
Herbana Street
La Paz, Iloilo City

60. – FARM HOUSE
12 San Inage Street
Tacloban City

61. – VICMAC INDUSTRIES
Mandalagan, Bacolod City

62. – JOSE DE LA VIÑA
Carvel, Km 1
Roxas City

63. – TAF ENGINEERING
Rotonda, Tabuco
Naga City

64. – DS FARM EQUIPMENT INDUSTRY
Anayan, Pili
Camarines Sur

65. – VELASCO IRON WORKS
990 Blumentrit Street
Naga City

Note: The Agricultural Machinery Testing and Evaluation Center (AMTEC) keeps a file of brochures for brands with asterisk (*)

APPENDIX II: Summary of Hand Tractor Features and Specifications

Features and Specifications

Brand	Prime Mover (hp-brand)	Body Length (cm)	Body Width (cm)	Body Weight (kg	Capcity ha/day)	Fuel lit/ha)	Type of Power Transmission	Location	Attachment
1. AQUABUG	16 hp Brigg and Stratton	150	100	200	1.5	17 gasoline	Chain drive and centrifugal clutch	Front	Puddling wheel
2. TURTLE	12-16 hp gasoline engine, 10-11 light weight diesel engine (Ducati or Lombardini)	140	111	165	1.5	8 gasoline 4 diesel	Belt tension	Front	Puddling whell
3. ADRIATICA									
a. Lince	5 hp Adriatica gasoline engine	–	85	50	–	–	–	Mid	Rotavator
b. Pantera	8 hp Adriatica gasoline engine	–	110	87	–	–	–	Mid	Rotavator
c. Tigere	10 hp Adriatica gasoline	–	150	145	–	–	–	Mid	Rotavator
4. ALPHA	11 hp diesel	187	45	160	1-1.5	3.5-4.5	Belt tension	Mid	Cage wheel, peg-tooth harrow, mouldboard plow, rotary tiller
5. ANOS	7 hp gasoline engine	–	–	–	–	–	Belt tension	Mid	Cage wheel, plow, peg-tooth harrow, operator seat
6. BANAUE	10 hp gasoline engine	200	95	195	0.6-1(rotavation) 1.3-2(rake harrowing) 0.6-2(plowing)	–	Belt tension	Mid	Rotavator, harrow, cage wheel, disc plow, mouldboard plow
7. BM	7-8 Honda	–	–	–	–	–	Belt tension	Mid	Spiral plow, harrow, trailer

(Continued)

Features and Specifications

Brand	Prime Mover (hp-brand)	Body			Capacity (ha/day)	Fuel (lit/ha)	Type of Power Transmission	Location	Attachment
		Length (cm)	Width (cm)	Weight (kg)					
8. BUFFALO	7-10 hp Briggs and Stratton	85	50	110 (without engine)	0.4(rotavation) 1.5(harrowing)	–	Belt tension and multispeed transmission gear system	Mid	Spiral plow, mouldboard plow, leveling board, harrow
9. CARABAO	6 hp Lombardini	–	–	–	–	–	Belt tension and multispeed transmission gear system	Mid	Rotavator, spiral plow, cage wheel
10. CIRON	6-7 hp Honda	–	–	–	1.0	–	Clutch pulley	Mid	Spiral plow, mouldboard plow, peg-tooth harrow, disc plow/harrow
11. FARM	8 hp Briggs and Stratton or Honda gasoline	226	136.5	120	1.0	–	Belt tension and multispeed chains and sprockets transmission system	Mid	Spiral plow, puddling, cage wheels, peg-tooth harrow, trailer, ridger
12. FILIPINAS	8 hp Briggs and Stratton	210	127	–	–	1.1	Belt tension	Mid	Mouldbard plow, spiral plow, pneumatic tires, puddling wheel, leveling rake
13. HERCULES MB11	10 hp Briggs and Stratton	270	130	251	1.0	8-12 gasoline	Clutch pulley with disc	Mid	Spiral plow, mouldboard plow, peg-tooth harrow, disc plow/ pharrow
14. LAKAS ELEPANTE	7-16 hp Briggs and Stratton	–	–	185	1 (plowing) 2 (harrowing)	8 (plowing)	Chain and sprocket drive	Mid	Spiral plow, roller, puddling wheel, trailer, upland cage wheel, moulboard plow, penumatic tires, disc plow
15. LAKAS KULIGLIG	10 hp Briggs and Stratton	96	48	96	1 (plowing) 1.5 (harrowing)	8 to 9 (plowing)	Belt tension (and clutch lining)	Mid	Spiral plow, peg-tooth harrow, roller, mouldboard/disc plow
16. LIMBAS	8-10 hp Briggs and Stratton 10 hp Honda 9 hp Ducati 6 hp Petter	216	111	104	–	–	Belt tension	Mid	Roller, spiral plow, mouldboard plow, harrow, puddling wheels, twin disc harrow, rotavator wheel
17. MAGICO	6-10 hp Briggs and Stratton/ Honda 7 hp Ducati or Lombardini Diesel engine	–	–	–	1.0	–	Belt tension	Mid	Mouldboard plow, peg-tooth harrow, rotavator
18. OBERLY	8-10 hp Briggs	–	–	–	–	–	Belt tension	Mid	Mouldboard plow, puddling wheels, leveling rake, pneumatic tires
19. PHILAND	10 hp MAG kerosene engine or 8-11 hp Intermotor engine	213	71	–	1.0	8.0	Belt tension	Mid	Disc plow, mouldboard plow, spiral plow, paddy cage wheel, peg-tooth harrow
20. RS a. M-111	16 hp Briggs and Stratton Tecumseh gasoline engine	194	61	70.5	–	–	Belt tension	Mid	
b. M-222A	8-10 hp Briggs								Rotavator,

(Continued)

Features and Specifications

Brand	Prime Mover (hp-brand)	Body			Capcity ha/day)	Fuel lit/ha)	Type of Power Transmission	Location	Attachment
		Length (cm)	Width (cm)	Weight (kg)					
and M-222B	and Stratton	184	58.5	59	–	–	Belt tension	Mid	spiral plow, cage wheels, cultivators, peg-tooth harrow, mouldboard plow
c. M-333	7 hp Briggs and Stratton and 6.5 hp Honda Honda G-65	80	58.5	58	–	–	Belt tension	Mid	
d. M-444	7 hp Briggs and Stratton	180	57.5	56	–	–	Belt tension	Mid	
21. SAGISAG	–	190	140	110	–	–	Belt tension	Mid	Leveling rake, puddling wheel, mouldboard plow
22. SM	7-10 hp Briggs and Stratton or or Honda	172	114	125	1.0	–	Belt tension	Mid	Spiral plow, peg-tooth harrow, trailer
23. SPRING-FIELD	7-10 hp gasoline engine	193	113	130	2.0	–	Belt tension	Mid	Puddling wheel, pneumatic tires, spiral plow, peg-tooth harrow, mouldboard plow
24. TAMARAW	8-10 hp Briggs and Stratton	–	–	–	–	–	Belt tension	Mid	Spiral plow, cage wheel, harrow
25. W B	8 hp Briggs and Stratton	220	109.2	71	–	–	Belt tension	Mid	Cage wheel, mouldboard plow, rotavator, rubber tires, spiral plow, harrow
26. WILCON	7-15 hp Briggs and Stratton	–	–	–	–	–	Belt tension	Mid	Spiral wheel, cage wheel, harrow

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7-2 Kanda Nishikicho, Chiyoda-ku, Tokyo, Japan (Tel. 03/291–5717~8, 3671~4)

Orchard Machinery in Japan

by
Kozo Hirata
Head
Fruit Horticulture Machinery Laboratory
Institute of Agricultural Machinery
1-chome, Nisshin-cho, Omiya-shi
Saitama-ken, Japan

Introduction

Fruit production in Japan is characterized by small scale and also hillside farming. Hence, fruit growers try to intensify yields, produce high quality fruits through modern technology. With the exception of pest control by machinery, it is difficult to mechanize fruit growing in Japan.

Two leading fruits grown in Japan are citrus and apple. Citrus production area represents about 40% of all fruit areas in the country. On the other hand, the area for apple production decreases yearly due to its high labor requirement. Citrus Unshu (Satsuma orange) is planted on steep, sloped hillside in the west coastal area where warm weather prevails. In comparison, apples are grown in the northern part of the main land where the climate is cool. Fruit production requires greater labor than other crops. **Tables 1** and **2** show the labor requirement for citrus and apple production, respectively. In both cases, about half of the total labor is used in harvesting. It is, therefore, in the harvesting operation where labor-saving devices, hence mechanization needs to be developed.

The net per capita income in a day earned by fruit growers is shown in **Table 3**. Income from citrus production is low compared with apple production. Gross income from rice production is higher than for fruit production. But the net income per a unit area is higher for fruit than for rice growing because much of the labor for fruit growing is supplied by the farmers' family.

Table 4 shows the field operation for important fruit trees, including machine use. Small machinery for special purpose are used for orchard operation except the air blast sprayers for pest control in apple production.

Table 1 Required Labor for Citrus (Unsyu) Production (1977)

Operation	Required Man-hrs/ha
Harvesting	84.1
Thinning	28.5
Pest control	23.1
Topworking	15.1
Cultivating and weed control	29.6
Fertilizing	7.6
Bagging	0.1
Miscellaneous	9.9
Total	198.0

Table 2 Required Labor for Apple Production (1975)

Operation	Required Man-hrs/ha
Harvesting	84.1
Fertilizing	4.2
Cultivating and weed control	9.9
Pest control	19.3
Pollination and thinning	63.4
Bagging	57.1
Frost control and wind control	1.5
Topworking	30.9
Irrigation and others	14.6
Total	285.0

Table 3. Comparative Daily Income from the Production of Citrus, Apple and Rice, 1940–75

(Unit: Yen)

Crop	1960	1965	1970	1971	1972	1973	1974	1975
Citrus (Unsyu)	2,150	3,058	4,144	4,091	1,570	2,601	3,443	1,986
Apple	1,028	1,299	2,714	2,572	3,529	4,006	5,051	9,162
Rice	1,048	2,008	2,493	2,308	3,004	4,084	5,675	6,983

Tractor and Tillage Equipment

Almost all tractors used in orchards are the small walking-tractors because of their versatility compared with the four-wheeled tractors in small scale and hillside operations. Walking-tractors are used in land cultivation. Before the introduction of pick-up trucks, the walking-tractor was also used for hauling in orchards. These small tractors are also used for weed control and mowing. As the method of soil management in orchards changed from clean culture to sod culture, the non-cultivation system in orchards became popular. On the other hand, orchards employing walking tractors for cultivation and weed control in early spring, to reduce soil compaction and to hasten the growth of roots

Table 4 Machinery and Use in Fruit Production

Use	Machinery and Equipment
Topworking	Scissors, saw, chain-saw, shredder
Fertilizing	Broadcaster
Thinning	Sprayer
Cultivating	Walking tractor
Weed control	Power scythe, walking rotary mower, rotary cutter
Pest control	Sprayer, spraying system with pipe line, air blast sprayer
Irrigation	Sprikler system with pipe line
Hauling	Truck, miscellaneous vehicles, monorail for hillsides

Fig. 1 Up-cut rotary tiller

are increasing in number. The walking tractor for this purpose is a special type that is equipped with front mounted up-cut rotary tilling device and is designed to cultivate the soil under the trees easily. **(Fig. 1)**

Twenty years ago, about 2,000 four wheeled tractors were used to tow the air blast sprayer in apple and peach orchards. Since then, these tractors diminished in number with the advent of self-propelled sprayers.

For some large-scale orchards, the four-wheeled tractor is still used but in limited operations only.

Topworking

Pruning and training the branches of fruit trees are a important operations for producing high quality fruits and also for simplification of all field operations. As these operations are expected in winter, it is not necessary to mechanize them, particularly for small scale farming. Prunning scissors and saw have become popular lately, some of which are manufactured by local and special manufacturers. For cutting big branches, chain saws are commonly used. **(Fig. 2)**

Due to urban development alongside fruit production areas and to air pollution, burning of pruned limbs or branches has been discouraged. As a result, special machines have been introduced to chip or shred the pruned limbs and made into compost.

Fertilizer Application

Fig. 2 Chain saw

Fruit growing requires large amount of compound fertilizer, including organic matter. The fertilizer is applied on the soil surface or placed in holes or trenches around the base of the tree.

Much of the labor in fertilizer application is used in hauling in or out of the orchards. Actual application or the labor for scattering of the fertilizer requires small labor force. It is, therefore, necessary to rationalize the hauling of fertilizer with a view to reducing labor cost. In small scale farming, fertilizer is applied by hand compared with broadcasting for large scale farming. A large amount of organic matter must be applied in the orchard which is another operation that requires hauling, hence greater labor. In order to minimize hauling by man, many kinds of motorized haulers and diggers have lately become available in Japan. **Fig. 3** shows a typical machine for making trenches around the fruit tree.

Pest Control Machines

Pest control by chemical application is an indispensable operation in orchard management for both small and large farms. Timely and appropriate chemical application ensures the quantity and quality of fruits. For citrus, chemicals are applied about 10 times a year; apple, 15–20 times; and pear, 20 – 25 times. Since pest control operation requires a sizable labor, mechanized application of chemicals precedes all other mechanization efforts in orchard management. Add to this the fact that most chemicals are injurious to the health of the laborers.

Fig. 3 Ditcher

Fig. 4 Air-blast sprayer

Soon after World War II, orchard growers applied chemicals on plants by hand sprayer. After about 1950, the power sprayers were developed and put to commercial use. This development was followed by the introduction of the pipe-line system. This system is now most popular in fruit growing on steep, sloped hillsides. The air-blast sprayer system has been quickly adopted by apple growers, in particular. This type of sprayer has not been found suitable for Citrus Unsyu because of their high density planting on steep, sloped hillside. About 10 years ago, studies on the utilization of sprinkler system with pipe line for pest control were conducted to test their effectiveness in both efficiency and economic aspects. At the present time, however, the distribution of this spray system to orchard growers is limited due to its high retail price owing to high cost of construction, maintenance and operation.

Fig. 4 shows the most common air-blast sprayer.

Weed Control

The sod culture system has lately replaced the traditional clean culture system in supplying organic matter to the soil, controlling soil

Fig. 5 Power scythe

Fig. 6a Rotary mower

Fig. 6b Flail mower

Fig. 7 Hauling tri-wheeler

Fig. 8 Monorail for hillside haulage

erosion and saving labor in soil management.

Mowing the grass in the orchard or around the trees checks the competition for nutrient and water between the trees and the grass. The labor requirement of this system is about equal that required for pest control. Mowing efficiency in orchard is low because of small-scale nature of the orchard, high density planting and sloping surfaces. In addition, it is difficult for the machine to mow under the trees with low-hanging branches. Areas under the trees represents more than 50% of the total orchard area.

The small mower is the most suitable machine in Japanese orchards. The most popular type of mower in hillside orchards is the power scythe (**Fig. 5**). Orchard growers changed the sickle for power scythe in recent years as this machine proved indispensable for hillside orchards. Power scythes are the hanging type power cutter, driven by 1.0 to 1.5 PS engine and equipped with a circular blade of 20 to 25 cm in diameter. The total weight of a power scythe ranges only between 5 and 7 kg. It is capable of clearing orchards at the rate of 1.5 hours per 10 are. In level or slightly sloped orchards, the walking type rotary mower and flail mower are commonly used. The rotary mower is of simple construction and low cost. The flail type walking mower is a little complicated and costs more than the rotary type. The flail mower is suited for rugged terrain and controls grass growth for longer periods of time and can clean more than 20 are of orchard per hour. Both types of mowers are shown in **Fig. 6**.

Haulage

Over the last ten years, the labor requirement for fruit production has continued to decline and is being fast replaced by mechanization, including many other farm operations. Both the orchard growers and government have cooperated to construct feeder roads in the rural area, including the steep, sloped hillside to induce most motorized vehicles, to gain access to about 85% of all the orchards. Through this infrastructure and motorization, the hauling of farm inputs and products has been facilitated greatly not to mention the time saved by the orchard growers.

Hauling in and around the orchards is being hampered by the complexed natural land contours and the irregular spacing in tree planting. As such new kinds of small machineries are now in use, most popular of which is the walking tri-wheeler type, capable of 150–200 kg load. For the steep sloped hillsides, a small scale monorail was developed about 10 years ago and was immediately adapted. Today, more than 100,000 monorail units are in operation in Japanese citrus orchards. These monorails are characterized by easy setting of their rail without orchard reconstruction and are able to climb the hillsides with inclination of less than 45 degrees. The pick-up truck, however, is still the most useful and popular among these motorized units. **Fig. 7** shows a walking tri-wheeler type and a monorail in **Fig. 8**.

Harvesting

Harvesting is the most laborious series of operation in fruit production. It comes in four basic operations: picking the fruits, filling the field box with harvested fruits: changing the picking position from one point to another: and transferring the field boxes.

In Japan, all fruits are produced for the fresh produce market. All operations except hauling harvested fruits are executed by hand as any mechanical means could damage the fruits.

In order to color the skin of apple fruits by filtering the sun light and to protect the fruits from developing blemishes through insect bites and other causes, all fruits are bagged by hand using various materials such as plastic films and heavy paper as soon as they develop. The high market price of bagged fruits compensates for labor costs incurred in bagging. ■■

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   vi) bibliography
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Energy-Conserving Farming Systems for the Humid Tropics

by
Ray Wijewardene
Agricultural Engineer
International Institute of Tropical Agriculture
PMB 5320, Ibadan, Nigeria

Introduction

As the '70s' merge into the '80s', and distillusionment sets in with the 'green revolution', strategies for the future are reviewed. Understandably, the question that arises is 'where did we go wrong?'. Perhaps most wrong was the belief that the systems and techniques, apparently well proven in the temperature regions of the developed world could likewise prove a panacea for the productivity shortcomings of the lesser developed countries in the tropics. The high-inputs technology worked fine where input-availability and logistics had grown over the half century or so of its acceptance; first in Europe and then in North America. Crop-breeders selected and crossed for response to these high inputs and confident of their availability, (true enough for these regions of the north!). The agriculture machinery industry grew like the dinosaur, – in horsepower inputs, if not in numbers, – confident in the belief that 'bigger was better'.

The earliest suggestions that the reverse might be even better came with the world-wide acceptance of the compact automobile. This awareness was doubtless spurred by the more responsible of the major petroleum producers who realised that their reserves of 'black gold' were limited; and that a dramatic increase in price was probably the only way to emphasize the fact that oil, – as was learned earlier of wood, – was too valuable an industrial raw material to be burned.

Giles (1) in a chart of Agricultural Mechanisation suggests a correlation between yields and effective horse-power per hectare. This led to many an erroneous inferences in farm power texts that certain minimal horse-power levels per unit of land was an essential pre-requisite to higher production.

The error here was in the concept of mechanisation as the 'mechanising' (or 'tractorising') of manual, and of (later) animal-powered functions on the land. Engineers failed to question whether the tractor had, in fact, mechanised agriculture or the horse! The need for a re-evaluation of energy-efficiency in farming quickly revealed how inefficiently the tractor-tyre substituted for the horse's hoof!

F.A.O. (2) comparing yields against real energy inputs in the context of three quite differing rice production methods, revealed that modern (U.S.) agriculture produced 5,800 kg/ha for a fuel energy input of 15,451 k. calories; while transitional agriculture (Philippines) produced 2,700 kg/ha for a fuel input of 1501 k. calories; and traditional (also Philippines) agriculture produced yields of 1250 kg/ha for fuel (mainly food) inputs of barely 41 k. cal!

Pimentel (3) tables U.S. corn yields doubling in the 20 years between 1950 and 1970, – and also the price in inputs paid for this achievement. Labour was halved! Nitrogen inputs went up eight times! Phosphate and potash inputs increased three times; insecticide and herbicide inputs went up ten and twenty times, respectively. Crop drying inputs went up four times and electricity utilisation increased six times.

Such increases might well be justified in the context of North American farming with its prompt availability of these inputs from local sources backed by a well organised infrastructure which were developed over many decades. A very different situation prevails, however, under the socio-environmental and logistic constraints facing the developing nations in the humid tropics where the predominant agriculture is still shifting cultivation.

Research in recent years (4) (5) (6) (7) has, however, peered more deeply into reasons for the lower productivity of tropical arable farming, – apparently anomalous in the background of lush tropical greenery! Greenland (6) wisely foresaw, "for their development, they require not the transfer of technology but the devising of

a new technology". Perhaps a more appropriate technology for that environment and economy!

Physical Constraints

Most farm tools have developed over the ages for mitigating the time, energy and logistic constraints to the farmer's productivity. Traditional (manual) farming while conserving energy took long hours. The trend of mechanisation, hitherto, has been to reduce time by an exchange with a higher input of an alternative energy, whether animal or mechanical. Thus, for any particular system of agriculture, the product of ENERGY and TIME (E x T) remained roughly constant as illustrated – graphically in **Fig. 1**. (8) Conventional manual farming (the lower end of curve K-2) is low in energy but high in time.

Conventional mechanised farming (the upper end of the K-1 curve) is low in time but high in energy, (made up of a reduction in manual energy but supplemented by a very substantial increase in mechanical energy). Such an exchange might be acceptable only where the alternative fuels are readily available and the machines for converting these fuels to useful work are within the technical capabilities of the user much of which does not pertain to most of the developing world!

A feasible alternative would be a change in technology or methodology to one which is, appropriately, low in time and low in energy as suggested by curve K-2 in **Fig. 1**. The appropriate position on the K-2 curve being selected according to input and technological capabilities available. This is exactly what happened in the case of 'no-till' ('direct-drilling') farming as indicated by Matthews (9) under British farming conditions and more recently in large-scale trials at IITA (**Table 1**). Substantial reductions are achieved both in energy use (235 to 52 MJ/ha) and time (5.4 to 2.3 man-hr/ha), and representing a shift from the upper (mechanised) end of curve K-2. **Fig. 2** from data compiled by D. Couper over the years 1975 to 1978 clearly illustrates maize from zero-tillage ('no-till') fields continuing to maintain yields while those tilled conventionally decline after the second year of intensive, well fertilised (100 N per crop) double cropping. Profitability of 'no-till' maize was twice that achieved on conventionally tilled fields ($995/ha/yr. versus $465/ha/hr) (10).

Table 1 Energy and Time for Crop (maize) Establishment in Conventional and Zero Tillage Systems Under Large-scale Tropical Farming Conditions

Treatment	Number of Passes	Energy MJ/ha	Labour hr/ha
Conventional:			
Disc plow, disc harrow twice and plant	4	235	5.4
Zero tillage:			
Spray (herbicide) mow and plant	3	52	2.3

I.I.T.A. 1978, first season.

As the mandate for research at IITA was clearly orientated towards the small farmer our objective then was to 'slide' down to the lower (manual) end curve K-2; to an alternative and more appropriate system of farming that might be adopted by the small, 'non-mechanical' farmers in the developing tropical world.

Environmental Constraints

While the physical constraints of ENERGY, TIME, and LOGISTICS, remain universally the area of research for the agricultural engineer, these need clearly to be resolved within the context of environmental constraints particular to each particular region. Wijewardene (8) listed five environmental factors constraining agricultural productivity in the humid tropics; a) inadequate sunshine; b) intensity of

Fig. 1 Concept of alternate methodology in the context of energy and time for conventional and alternative farming systems (Wijewardene, 1978).

Fig. 2 Annual yields of maize cropped two seasons each year, zero-tillage versus conventional tillage using large scale (tractorized) equipment (Couper, IITA, 1979).

rainfall; c) consequent heavy erosion; d) rapid loss of fertility; and e) very considerable time spent controlling weeds.

It is rarely appreciated that the large leaves typical of truly tropical vegetation (the banana tree, the teak tree, the yams - taro, etc.) are for optimising (for photosynthesis) low solar radiation due to cloud or dust (harmattan) cover during the rain or dry season. In fact, solar energy can average as low as 300 and 350 cal. per cm^2 per day during the crop growing (rainy) months, or about half that available to a U.S. or Australian farmer on a summer day.

The implication for the tropical farmer is the need, therefore, to ensure as many crops as possible, either relay or sequential, to optimize periods of sun and rain thus making up over several crops the inevitably reduced yields achievable. (i.e., 4 to 5 tons/ha in two crops/year during the six months of rainfall as against the 3 to 4 tons/ha in one crop a year achieved in the semi-arid tropics or in temperate countries). Once the rains begin, time spent tilling the soil or preparing fields is valuable time lost for photo-synthesis.

The intensity of tropical rainfall is a major factor contributing to heavy erosion on tilled soils of the gently undulating terrain through most of the tropical country side. Greenland (6) and Lal show that this can be in the region of 1 ton of soil lost/ha/month (on 10% slopes) on tilled (plowed) land growing a crop of maize (corn). This is reduced to less than 0.02 tons/ha/month on the same land farmed 'no-till' **(Table 2)**. Run-off, too, is much higher on tilled land.

While temperate climates rarely experience rainfall intensities in excess of 75 mm/hour, (on the 7.5-minute – maximum-intensity basis), over 20% of the tropical storms exceed this intensity (11).

Table 2 No-Tillage Effects on Soil and Water Loss (during 4 months) Under Maize

Slope (degree)	Soil Loss (tons/ha)		Run-off (mm)	
	No-tillage	Plowed	No-tillage	Plowed
1	0.03	1.2	11.4	55.0
10	0.08	4.4	20.3	52.4
15	0.14	23.6	21.0	89.9

IITA first season data by Dr. R. Lal, published by Greenland D.J. in Vol. 190, (841–844) Nov. 1975.

In fact, intensities in excess of 50 mm/hour are observed for over 45% of the rain storms in the tropics where overall annual rainfall varies from 700 mm in the drier, semi-arid, areas to 2,000 mm in semi-humid and humid regions.

Weed control accounts for most of the time a tropical farmer spends on his field. Flinn (12) suggests a figure of at least 60%. Considering tillage, and similar land-preparation tasks, more correctly, as weed control, this could well be much higher!

Slash-and-burn, the original 'no-till' system, did not, usually, aggravate the problem of erosion. This was invariably precipitated by tillage for the subsequent crop to control the influx of weeds from the surrounding bush. But the small farmer had little alternative. Either he tilled to take advantage of the little remaining fertility for a second crop or he shifted to clear and burn elsewhere. It was only in the last decade that herbicide usage offered a really practical alternative to soil disturbance for control of weeds.

Particularly attractive here is the minute quantity of herbicide needed, barely 1–2 kg/ha; and the very low toxicity of most modern herbicides. Logistically, too, this is a small fraction of the problem of transporting the 200 to 400 kg/ha fertilizer requirement of the high-input technology. Lal (13) emphasizes an often overlooked fact that mulch, dessicated surface growth and crop residue, is an important factor in the success of the no-till technique as applied to tropical farming. It further reduces run-off and nutrient losses, reduces soil-temperature, and improves the soil chemical and structural properties. Increases in the order of well over 10 times have been recorded in both number and weight of worm casts on 'no-till' fields when compared with conventionally tilled land. In many semi-arid regions, the quantity of crop residue available for mulch is severely limited by cattle grazing on the fields between crops, and suggests a reason why 'no-till'' techniques might not prove as dramatic here as on soils of the humid regions where cattle populations tend to be less.

'No-till' for the Small Farmer

Early experience with the endeavour to adapt, for the small farmer, the techniques and technology already developed for large scale 'no-till' farming in the West, quickly revealed an unexpected anomaly. Whereas it might be feasible to scale up to mechanised power levels from animal or manual power levels, this is very rarely applicable in the reverse! The indulgence and inefficient use of energy in larger mechanized systems being magnified when reduced to manual levels! Thus attempts to scale down the sprayers and planters adopted on large-scale 'no-till' farming proved abortive!

The 300 to 500 li/ha requirement of conventional (tractor-mounted) sprayers would be logistically impossible for the small farmer on foot to tote on his back! Napsack spraying, while practical at home-garden scale, would limit the

Plate 1 Applying herbicide over stubble and weeds through the CDA (Controlled-Droplet-Applicator) at rates as low as 20 to 40 litres per hectre.

farmer to the bare half-hectare he coped with earlier and in no way provide for the goal of 5 and 10 times increase in acreage and productivity envisioned. The CDA (controlled-droplet-application) system developed by Bals (14) was, therefore, adopted for its reduced, 20 to 40 li/ha, herbicide application capability; and also for its low cost at about one-third the price of a napsack sprayer, and extreme simplicity (only one moving part, powered by flashlight batteries) **(Plate 1)**.

Seeding

Weeding and seeding are intrinsically complementary systems. The method and tool for seeding closely complements the method and tools for weed-control. Likewise, in 'no-till' farming systems special planters had necessarily to be developed to cope with the desirably high-trash field condition left by herbicide weed control. In Europe and the U.S.A. the 'triple-disc' seeder/planter developed as a heavier, more energy-consuming version of conventional planters. These proved totally impractical when scaled down for small farmer

Plate 2 The RIP (Rotary Injection Planter) planting an inter-crop through thick mulch and stover. In-row spacing is an accurate 25 cm, with seed firmed over by the compacting wheel.

use. An alternative range of 'jab' or injection type planters were, therefore, developed to insert seed through mulch and into soils at precise depth and spacing. Generally, these developed as automatic feed version of the well known early (circa 1900) U.S. corn planter, and enabled a farmer to plant a hectare of maize (usually 40,000 hills) in 15 to 20 hours.

It soon became apparent, however, that an even quicker planter was necessary to complement dramatic increases in productivity which were clearly becoming possible with these systems and tools.

Plate 3a The RIP-4, - 4 row injection planter injects four 'hills' of seed, simultaneously, through mulch and stubbles, with an upland rice field without need for prior tillage.

Rotary-Injection-Planting

A rotary version of the injection planter was then developed at IITA in association with the Washington based organisation VITA (Volunteers for International Technical Assistance). This RIP (Rotary-Injection-Planter) **(Plate 3)** comprises a series of injection points around the periphery of a wheel which could easily be rolled over a mulch covered field. Each point had its own ground-activated opener to deposit seed through the mulch and into the soil. A compacting wheel, also lowered wheel-barrow-fashion for transportation, follows to firm soil over the seed. A simple central metering device transfers the seeds from the hopper into each point as it descends into the soil.

Avoiding the problem of slicing through mulch and crop residue, the RIP requires remarkably little manual effort to propel. This is particularly appreciated by those with experience of the U.S. type of triple-disc planter which drags a wet, soggy mulch and stover along with the leading coulter,

Plate 3b The CDA herbicide applicator is here used, after planting (or direct-drilling) to apply pre-emergent herbicide.

despite such innovations as the 'ripple-disc' and added weight, in a vain endeavour to slice through a heavy crop residue.

Precise in-row plant spacing is achieved (25 cm being one standard popularly used) and enables an accurate (say 75 cm X 25 cm = 55,000 hills) planting of a hectare of maize to be achieved in 5 to 10 hours without recourse to tractor or animal power.

An alternative design for a 4-row manually-drawn planter **(Plate 4)** was also developed for the upland-rice farmer.

Planting an accurate (25 X 25 cm = 160,000 hills) of no-till upland rice is now achieved within 10 hours; a dramatic reduction in time and drudgery from the near 300 man-hour requirement of conventional hand dibbling or transplanting practises.

Fertilizer Application

The 'no-till' system and complementary tools resulted in such dramatic increases in productivity that other factors, hitherto eclipsed by the drudgery of weed control and planting, emerged as secondary constraints. Principal among these was the need for efficiency and economy in fertiliser application. While placement in the soil in close proximity to the seed would have been ideal, the fact that most commercial fertilizers were ill-suited to tropical use soon became apparent. The high humidity often resulted in the fertiliser being a soggy slurry one day, and rock-hard a few day later. Accurate metering for placement was clearly not possible until fertilizers were better developed for the climate and controlled-release needs of tropical farming. In the meanwhile a simple fertiliser band (surface) applicator was developed **(Plate 4)** to dibble a line of fertilizer at controlled rates (i.e. 20,30,40 gm/meter, etc) adjacent to the line of plants either upon emergence, as

Plate 4a The FAB (Fertilizer-Applicator-Band) laying a band of fertilizer alongside the line of plants; either as basal or top-dressing applications.

Plate 4c The small, upland-rice, farmer's range to complement the 'no-till' system. The CDA herbicide applicator; the 4-row injection planter and portable pedal-thresher.

Plate 4b This compact range of hand tools for the small farmer, – herbicide applicator; mulch planter, and fertilizer applicator – complements the 'no-till' system and increases productivity nearly ten-times !

Table 3 Comparison of Man-power Requirements for "No-Till" and Conventionally Tilled Fields Over Two Successive Seasons Using Hand-Tools Only Fashola, Nigeria (1978).

Field Operation	First Season Man-hrs/ha		Second Season Man-hrs/ha	
	Conv.	No-till	Conv.	No-till
A. Field Preparation:				
a. Burning	4	4		
b. Clearing, slashing	132		76	
c. Manual tillage & ridging	127		85	
d. CDA Spray, (contact-herbicide)		8		6
B. Seeding (maize and cowpea)				
a. Manual planting (low population)	35		35	
b. Planting; –RIP (Rotary Injection Planter) (25x75 = 53,000 stand/ha)		13 (1)		9
C. Pest control				
a. Manual weeding, - once (2)	190	4	150	3
b. CDA spray (pre-emergent-herbicide)		9		5
c. CDA spray (cowpea) insecticide, - thrice		2		2
D. Fertilizer application:				
a. Manual dibbling along rows	25		25	
b. Using IITA fertilizer band applicator (3)		8		8
Totals: a. Man-hrs per hectare	513	48	371	33
b. Yields maize/cowpea kg/ha (4)	600/ 500	1773/ 2020	500/ 400	1112/ 1820

Note: 1. Two additional men were employed to lay ropes for lining up the planting rows during the first season only. The line of stubble provided ample lining for the second and subsequent seasons planting.
2. Occasional manual spot weeding was undertaken on no-till plots to eradicate resistant weeds.
3. The fertiliser-band-applicator was used for basal application on both maize and cowpea, and for top-dressing, also on maize.
4. Yields obtained by the farmer from conventionally tilled plots had to be approximated.
5. Crops grown were maize and cowpea, planted on separate fields.

basal application, or as top dressing. Rates of operation of well under 5 hours/ha/application were achieved, and considerable improvements in crops became evident resulting in its immediate popularity with the small farmers for whom this tool was designed.

Operational Performance

Wherever the systems and complementary tools have been demonstrated acceptance has been enthusiastic as farmers quickly appreciated the benefits of the erosion control, weeding and planting methods demonstrated. This has also provided useful feed-back of performance from trials on farmers fields.

Table 3 compares the dramatic reduction in operational time to establish the first and also second season crops of maize and cowpea using the no-till system, versus the farmers' performance using conventional manual tillage systems and tools. Time for the establishment of the first crop was reduced from 513 to 48 man-hours/ha, and for the second crop from 371 to 33 man-hours/ha, thus demonstrating a potential increase in productivity by more than ten times (i.e., 1,000%). Yields too were greatly improved consequent upon the uniformity in plant population and excellent weed control achieved with consistant placement of fertilizer at optimal intervals. Particularly impressive was the facility, now, for the farmer to harvest his first crop of maize at, say, 30% moisture content and convey this to cribs for drying down to equilibrium while he directly planted his second-season crop with spray control of weeds for optimal utilisation of available sunshine and moisture.

Table 4 provides similar data for the farming of upland rice; notoriously high in labour inputs when grown traditionally (930 man hours/ha from field preparation to crop maturity, including 4 hours of hired tractor time for preparatory rough tillage). One alternative system is also illustrated which utilizes the power-tiller for field preparation after which seed is broadcast and subsequent weed growth controlled by herbicide spraying. Twenty five hours of power-tiller time are used plus over 50 hours of the farmers' time.

The 'no-till' method reduced these to no-tractor hours and barely 44 man-hours for planting, weed control and fertilizer application, thus demonstrating an improvement in productivity well over 10 times that for conventional manual methods. Very favourable comment has consistantly been expressed on the uniformity of a field drilled by the IITA 4-row planter which emerges looking very much like a (laboriously) transplanted field.

Consistent yields in the region of 6,000 kg/ha have been achieved, twice each year, on farmland thus planted to 'no-till' upland rice.

Summary and Conclusions

An appropriate mechanisation for tropical agriculture is believed to commence with the development of an appropriate system: one which is appropriate to the

Table 4 Comparison of Man-hour and Tractor-Hour Inputs for Growing a Hectare of Upland Rice by Three Different Small-Farmer Systems with Similar Yield Potential

Field Operations	Conventional(1)		Minimum-Tillage(2)		No-Till(3)	
	Tractor hrs/ha	Man hrs/ha	Tractor hrs/ha	Man hrs/ha	Tractor hrs/ha	Man hrs/ha
A. Tillage/Pre-sowing:						
a. Hired tractor tillage plus tillage	4	120				
b. Rotary tillage (2 wheel tractor)			25	25		
c. CDA spraying of contact herbicide					–	9
B. Seeding/planting						
a. Seeding (hand dibbling in rows)	–	300				
b. Broadcasting of seed			–	4		
c. Direct planting (IITA 4-row seeder)					–	12
C. Weed control						
a. Manual weeding by hand hoe x 2	–	500				
b. Napsack spraying of post-emergent herbicide			–	19		
c. CDA spraying of pre-emergent herbicide					–	19
D. Fertilizer application						
a. Broadcast in 3 applications	–	10	–	10		
b. Band application; inter-row x 2 + broadcast x 1					–	14
Totals: Tractor-hrs per hectare	4		25		nil	
Man-hrs per hectare		930		58		44

Note: 1. The 'conventional-tillage' farmer hired a 4-wheel tractor for initial tillage followed by manual hoeing, seed-dibbling in rows, and inter-row hand-hoeing (twice). Data supplied by Nigeria's N.A.F.P.P. (1975).
2. The 'minimum-tillage' farmer use a two-wheel tractor for primary tillage, followed by broadcasting of pre-germinated seed. Subsequent weed control was by napsack spraying of post-emergent herbicide. (Data: IITA 1978, 1979)
3. The 'zero-tillage' farmer used no tractor, and CDA application of herbicide twice. Seeding was at 160,000 hills per hectare planted by the IITA 4 row upland rice planter. The first two applications of fertiliser were through the IITA and applicator in alternate rows while the final (top-dressing) was broadcast. (Data: IITA 1978, 1979)
4. Yields from all three fields were above 5,000 kg/ha (variety BG 90-2) with highest yield (7,000 kg/ha) attributed to precision application of fertilizer, precise plant population, and weed-control in the 'No-till' field.

Plate 5a The IITA 5 h.p. 'FARMOBILE', – or 'CHIEF' as it is known in some regions, – driving out to the field fully equipped with herbicide applicators, seed-drills, and trailer.

Plate 5b The IITA 5 h.p. "FARMOBILE' applying contact herbicide 4 metres wide over weeds and crop residue.

Plate 5c The FARMOBILE 'injection'-planting two rows of crop and simultaneously applying pre-emergent herbicide behind.

environment and the carefully analysed constraints to a farmer's productivity within that ecology. Only then are tools developed to enable each particular economic level of farmer to adopt the system well within his purchasing capability. And also without the capital indebtedness usually associated with a plunge into 'tractorisation'.

The world renowned crop breeder and agronomist Norman Borlaug, seeing the system and complementary tools demonstrated in 1977, remarked, "Nowhere is a system and range of tools which are really scale-neutral, to enable the small farmer hold his own, anywhere in the world. The small farmers in the U.S. and Europe need to adapt to this technology, too!"

But what, still, are the limitations to the system? One limitation is the extent the farmer can now aspire to crop manually, each season, without recourse to a tractor. **Tables 3** and **4** clearly illustrate the facility for a ten-times increase from barely half a hectare that he coped with hitherto (and this is universal throughout the humid tropics) now, to at least 5 or 7 hectares, with occasional family help. Above this the drudgery of walking over the field, perhaps 10 km/ha/operation, became a new constraint.

Development next progressed towards enabling the farmer to sit while performing his farm operations. The smallest practical motor was selected at approximately 5 h.p. (whether diesel or petrol fuelled) and a system developed around this with comprehensive capability for transportation (a trailer capacity of 1/2 ton); for CDA herbicide application up to 4 meters wide; and for 'no-till' (mulch) planting of at least two rows simultaneously.

The "Farmobile" - or "Chief" **(Plate 5)** as it has been named in some countries where it has been used, was developed for very easy manufacture locally in the developing world. An increase in productivity through this intermediate level of mechanisation to about 20 ha/season now becomes feasible.

But still new constraints appear. How will the farmer cope with the harvest of a five and ten times increase in productivity? How will he cope with the logistics of inputs and crop-handling from so dramatic an increase in production?

That is another story, and upon which research is currently engaged.

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Systems Approach in Scheduling Harvest and Post-Harvest Operations

by
S. Swain
Lecturer
Department of Agricultural Engineering
B.C.K.V.V, K
Kalyani, India

T.P. Ojha
Head
Rice Process Engineering Centre
Indian Institute of Technology
Kharagpur, India

Abstract

Agricultural products, like all industrial products, pass through different stages and operations before they are made available to the consumer. At each stage of production a number of alternate methods or machines are used for one operation. Computer alogorithms based on net-work analysis and dynamic programming models have been developed to find out the combination of methods or machines from a net-work representation of systems to give optimum (minimum) and near optimum cost of production. The results obtained for holding sizes of 1 to 27.5 hectares may help the farmers or farm managers in decision-making under prevailing limitations.

Introduction

A major feature of agricultural production is the large number of different machines and methods in use for one operation. These machines or methods can be combined in different ways and the number of feasible systems available is likely to be very large. Well developed accounting and work study techniques can be used for evaluating individual operations, but methods for determining the combination of machines at different stages to form optimum or near optimum system is little known. The machines or methods in use at different stages of production which give a very large number of feasible combinations can be represented by a general network for the whole operation. It is now possible to evaluate optimum or near optimum cost combinations by computer algorithms and application of dynamic programming.

The optimum and near optimum systems for different size holdings has been considered for the present study and is limited to post-harvest operations of paddy crop, the leading crop of India.

Materials and Methods

Three stages, namely; harvesting, threshing and drying each consisting of different operational methods were considered. A simplified dynamic programming network of some of the alternate methods of producing paddy is shown in **Table 1**. The principle of dynamic programming was applied to evaluate the optimum and near optimum cost routes. The capacities of harvesting machines, threshers and driers were obtained from test reports as well as from information supplied by the manufacturers. The cost per unit of products by alternate methods at a given stage was determined. For manual methods of harvesting, threshing and pedal thresher the costs were taken from farm records[1,2]. The unit cost of drying by conventional sundrying and mechanical drying were taken from the reports of the National Cooperative Development Corporation[3]. The available period for harvesting of paddy crop was considered to be 15 days based on timeliness function[4]. The available period for each threshing and drying stages was considered to be 18 days from the point of view of starting work for the following crop (**Fig. 1**).

Models and Computation

The whole process was divided into four stages such as harvesting, threshing, drying and final stage is shown in **Fig. 2**. A dynamic network of the post-harvest process was drawn as shown in **Fig. 3**. The serial number of machines or methods at each stage were maintained as in **Table 1**. A computer programme was used to evaluate the optimal and near optimal routes. The programme developed in FORTRAN II was based on the following models.

Table 1 Details of Operations and Methods

Stage	Method of Operation	Description
Harvesting	1.Manually	Twenty workers team
	2.Bullock drawn reaper	One unit
	3.Bullock drawn reaper with engine operated cutter bar	One unit
	4.Power tiller harvester	One unit
	5.Tractor operated self-raking reaper	One unit
	6.Tractor front mounted reaper windrower	One unit
	7.10 hp self-propelled reaper binder	One unit
	8.JF Vicon Combine	One unit
	9.12 hp combine harvester	One unit
	10.105 hp GDR combine	One unit
Threshing	1.Manually (beating on the plank)	Twenty workers team
	2.Pedal thresher	Twenty workers team
	3.Kubota Power Thresher (electric motor operated)	One unit
	4.Kubota Power Thresher (power tiller operated)	One unit
	5.Jyoti Multicrop Thresher (electric motor operated)	One unit
	6.Jyoti Multicrop Thresher (power tiller operated)	One unit
	7.Double drum thresher (10 hp diesel engine)	One unit
	8.Double drum thresher (power tiller operated)	One unit
	9.Vicon Thresher	One unit
Drying	1.Sundrying	80*, 50**
	2.Sundrying	80*, 100**
	3.Sundrying	24*, 50**
	4.Mechanical drying	80*, 100**
	5.Mechanical drying	80*, 150**

* Capacity, Tonne/day
** Operation period, days/year.

Fig. 1 Diagram of sequential operations after start of harvest

$$CI(MI) = AH(I) + BH(I)/F(J) \quad (1.1)$$

Where

CI(MI) = cost per unit product by machine I at harvesting stage, Rs./Qtl;
AH(I) = constant for Ith machine;
BH(I) = constant for Ith machine;
F(J) = size of holding; ha;
I = 1,10

and

$$C_2(MI) = ATH(I) + BTH(I)/F(J) \quad (1.2)$$

Where,

$C_2(MI)$ = cost of unit product by machine I at threshing stage, Rs./Qtl;
ATH(I) = constant for Ith machine at threshing stage;
BTH(I) = constant for Ith machine at threshing stage.

$$TH(I) = F(J)/CAPI(I) \quad (1.3)$$

Where,

TH(I) = Performance time of Ith harvesting machine; days;
CAPI(I) = capacity of Ith harvesting machine; ha/hr;
I = 1, 2, ..., 10

and

$$TT(I) = 6.25F(J)/CAP\,2(I) \quad (1.4)$$

Where,

TT(I) = performance time of Ith threshing machine, days;
CAP2(I) = capacity of Ith thresher, Qtl/hr;
I = 1, 2, ..., 9;

The application of the principle of optimality lead to the relations[5]

$$f_N^{(k)}(X) = \min_i k\,(f_{N-1}^{(I)}(T_i(x),$$

Fig. 2 Decomposition of the process into different stages

Fig. 3 Dynamic network of the post-harvest process

$$f_{N-1}^{(2)}(T_i(x)), \ldots\ldots\ldots\ldots$$

$$f_{N-1}^{(k)}(T_i(x)) \qquad (1.5)$$

$$(N = 2, 3, \ldots\ldots\ldots)$$

$$f_1^{(k)}(x) = \min_i k\, g(T_i(x)) \qquad (1.6)$$

Results and Discussion

The combination of methods or machine to give optimum and near optimum cost of production for different holdings were obtained. The optimum and some near optimum cost combinations for 1 hectare holding size is presented in **Table 2**. The minimum and maximum production cost are due to systems consisting of manual harvesting (by sickles), pedal thresher with mechanical drying (80,150) and tractor front-mounted reaper winnower, manual threshing (flailing) with sundrying (80,50).

The same cost of production Rs. 14.67 per quintal was achieved by system combinations (a) power tiller harvester-manual threshing – mechanical drying (80,50) (b) tractor operated self-raking reaper – pedal thresher – sundrying (80,50).

Conclusion

The cost of production per unit yield decreases with increase in farm size for a particular combination. The traditional method of manual harvesting and threshing are suitable for 1 hectare holding. Improved machines utilizing human and bullock power are suitable for 2-hectare holdings. Power tiller harvestor, power-tiller operated thresher with sundrying are most appropriate combination for holding in the range of 5 to 10 hectares. The combines are suitable for farms of 25 hectare or larger.

Table 2 Optimum and near optimum systems and their respective costs for 1.0 hectare holding

Harvest-ing	Thresh-ing	Dry-ing	Cost Rs./Qtl
1	2	5	12.01
1	2	2	12.11
1	2	4	12.21
1	2	1	12.37
1	2	3	12.52
1	1	5	12.73
1	1	2	12.83
1	1	4	12.93
1	1	1	13.09
1	1	3	13.24
4	2	5	13.75
4	2	2	13.85
4	2	4	13.95
4	2	1	14.11
4	2	3	14.26
5	2	5	14.31
2	2	5	14.39
5	2	2	14.41
4	1	5	14.47
2	2	2	14.49
5	2	4	14.51
4	1	2	14.57
2	2	4	14.59
4	1	4	14.67
5	2	1	14.67
2	2	1	14.75
5	2	3	14.82
4	1	1	14.83
2	2	3	14.90
4	1	3	14.98
5	1	5	15.03
2	1	5	15.11
5	1	2	15.13
2	1	2	15.21
5	1	4	15.23
2	1	4	15.31
5	1	1	15.39
2	1	1	15.47
5	1	3	15.54
2	1	3	15.62
6	2	5	17.40
6	2	2	17.50
6	2	4	17.60
6	2	1	17.76
6	2	3	17.91
6	1	5	18.12
6	1	2	18.22
6	1	4	18.32
6	1	1	18.48
6	1	3	18.63

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Time and Costs of Loans for Pumping Sets/Tubewells for Small-Holders

by
A. C. Sharma P. P. Setia
Farm Economist
Department of Economics & Sociology, Punjab Agricultural University
Ludhiana, India.

In 1971, the Indian Federal Government created the Small Farmers' Development Agency (SFDA) and the Marginal Farmers' and Agricultural Labourers' Development Agency (MFALA) for arranging credit facilities to the rural poor area through cooperatives and commercial banks at the subsidised rate of interest. These institutions were amalgamated into one organization - Small/Marginal Farmers' and Agricultural Labourers' Agency (SMFALA) in 1974 for serving both the small and marginal farmers and agricultural labourers. This Agency has been promoting such location-specific and economically viable programmes backed by subsidized credit through cooperatives and banking institutions such as the popularization of tube-well irrigation on small holdings.

To obtain credit for the installation of a pumping set/tube-well through the SMFALA, the farmer-borrower has to put in his application on the prescribed form seeking such information as his name and address, ownership rights in land, area irrigated, market value of land, land revenue assessment, liabilities, current and previous year's cropping patterns, farm costs and income, value of the produce consumed by the family and estimated off-farm income and annual family expenses. This application is to be supported by documents like (i) *Khasra Girdawari;* (ii) *Fard Jamabandi;* (iii) Guarantee by a Third Party; and (iv) No Dues Certificates from cooperative and other agencies extending financial assistance to the agricultural sector in the area. Besides, the application must be attested by such government functionaries as the *Patwari* and *Tebsildar* and processed and forwarded by the Block Development and Panchayat Officer and the SMFALA to the Land Mortgage Bank. The latter considers the application and sanctions the loan which is disbursed partly in kind and partly in cash. The former component is intended for the purchase of engine/notor from an authorized dealer while the latter is for its installation in the field. The installation of the machine involves the costs of the pump with base plate, pipes and pipe-fittings, boring, and construction of the water distribution tank. This procedure for obtaining loans arranged by the SMFALA is very cumbersome, complicated and time consuming and the farmer-borrower has to incur substantial amount of expenditure in the process of completing these formalities.

This paper is an attempt at investigating the pattern of loans for the small holders in India through the SMFALA for the purpose of installing pumping sets/tube-wells and the time and money costs involved in obtaining these loans with a view to identifying the need for the rationalization of the prescribed procedure.

Methodology

The present investigation was conducted in Ferozepur district which had the distinction of being the lead district in the Punjab State in terms of the SMFALA operations. Out of the nine Blocks comprising the district, the inquiry was concentrated in Ghall Khurd Block where the largest number of farmers had benefitted from this credit institution.

The study sample was selected following the two stage random sampling technique. The villages formed the primary and operational holdings the ultimate units of inquiry.

Ten per cent of the villages where the SMFALA had extended its activities were randomly selected without replacement from the sample Block. The farmers in the sample villages who had availed themselves of the credit facilities for the installation of pumping sets/tube-wells were stratified* into two categories: (i) small farmers owning between 2 and 3 hectares, and (ii) very small farmers owning between 1 and 2 hectares. A sample of 50 per cent farmers from each category was selected randomly and without replacement. Thus, 18 small and 16 very small farmers were randomly selected.

The information was collected in 1977–78 with the help of specially designed and pre-tested questionnaires using the survey method.

The difference of proportion of response on the pattern of pumping set/tube-well loans obtained by both small and very small farmers through the SMFALA was tested by running the 'Z' test, using the following relationship:

$$Z = \frac{P_1 - P_2}{SE}$$

Where,

P_1 = Proportion of success in population I

P_2 = Proportion of success in population II

$$SE = \sqrt{pq\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}$$

Where,

$$p = \frac{n_1 p_1 + n_2 p_2}{n_1 + n_2}$$

$q = 1 - p$

n_1 = Number of observations in population I

n_2 = Number of observations in population II

*Prior to 1975, Small farmers with holdings between 1 and 3 hectares and later with holdings between 1 and 2 hectares were eligible for the assistance offered by this agency.

The variations in the time and costs involved in obtaining credit through the SMFALA were examined within each category of farmers by working out the coefficients of variation as below:

$$CV = \frac{\sigma}{\bar{X}} \quad 100$$

Where,

CV = Coefficient of variation

σ = Standard deviation

$$= \frac{\Sigma X^2 - (\Sigma X)^2 / n}{n - 1}$$

$\bar{X}$ = Mean value of the cost component

X = Value of the cost component

n = Number of observations

The difference in the time and costs of obtaining credit through the SMFALA between the two farmer categories was statistically tested by applying the student's 't' test employing the following formula:

$$t = \frac{\bar{X}_1 - \bar{X}_2}{S\sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

Where,

$\bar{X}_1$ = Mean value of the cost component of population I

$\bar{X}_2$ = Mean value of the cost component of population II

s = Standard error

$$= \sqrt{\frac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2 - 2}}$$

$$s_1^2 = \frac{\Sigma (X_1 - \bar{X}_1)^2}{n_1 - 1}$$

$$s_2^2 = \frac{\Sigma (X_2 - \bar{X}_2)^2}{n_2 - 1}$$

Pattern of Loans Received

The percentage distribution of sample farmers according to the amount of loan received is shown in **Table 1**.

It is evident from **Table 1** that 61 per cent of the small farmers and 44 per cent of the very small farmers received loans in the range of Rs 3,700–4,700 for the installation of pumping sets/tube-wells. Loans varying from Rs. 2,700 to Rs. 3,700 were obtained by 28 per cent of the small farmers and 44 per cent by the very small farmers. In a few cases (11 per cent small and 12.50 per cent very small farmers), the loans amounted to Rs. 4,700 and above. Thus, a majority of the sample farmers (53 per cent) obtained loans

Table 1 Per Cent Distribution of Sample Farmers by Amount of Loan Received

Loan in Rupees	Small Farmers	Very Small Farmers	All Farmers
2700 – 3700	27.78 (5)	43.75 (7)	35.29 (12)
3700 – 4700	61.11 (12)	43.75 (7)	52.94 (18)
4700 and above	11.11 (2)	12.50 (2)	11.76 (4)

Figures in parentheses indicate the number of farmer-borrowers.

Table 2 Values of Components for Pumping Set/Tubewell Loans

Total Loan (rupees)	Average Total Loan (rupees)			Value in Rupees of the Kind Component of the Loan		
	Small Farmers	Very Small Farmers	All Farmers	Small Farmers	Very Small Farmers	All Farmers
2700 – 3700	3,040	3,028	3,033	1,656 (55)	1,529 (51)	1,582 (52)
3700 – 4700	3,970	3,957	3,965	1,951 (49)	1,936 (49)	1,945 (49)
4700 and above	5,500	5,000	5,250	2,400 (44)	2,160 (43)	2,280 (43)

Figures in parentheses indicate the percentages of the average amount of total loan.

ranging between Rs. 3,700 and Rs. 4,700.

The proportion of small farmers who obtained loans in the ranges of Rs. 2,700–3,700; Rs.+3,700–4,700; and Rs. 4,700 and above were not significantly different from those of the very small farmers. The 'Z' values in these cases were calculated at 0.92, 0.98 and 0.2, all of which ware non-significant at 5 per cent confidence level.

The farmer-borrowers were asked about the cash and kind components of the pumping set/tube-well loans. The information about the latter is presented in **Table 2.**

It is apparent from **Table 2** that for loans ranging between Rs. 2,700 and Rs. 3,700 the average amount of total loans for pumping sets/tube-wells were to Rs. 3,040 for small and Rs. 3,029 for very small farmers. The values of the kind component were estimated at Rs. 1,656 and Rs. 1,529 constituting 55 and 51 per cent of the average amount of the total loans, respectively. The average amounts of loan of the small and very small farmers who received Rs. 3,700 – 4,700 were Rs. 3,970 and Rs. 3,957. The kind components were valued at Rs. 1,951 and Rs. 1,936 accounting for 49 per cent each of the total loans. Far borrowers who obtained loans of Rs. 4,700 and above, the averages were Rs. 5,500 and Rs. 5,000 for the very small farmer. The value of the kind component was estimated at Rs. 2,400 for the former and Rs. 2,160 for the latter category of farmers. This component comprised 44 and 43 per cent of the loans advanced to the small and very small farmers, respectively. Thus, the kind component of the pumping set/tube-well loans ranged between 43 and 55 per cent of the total loan.

Table 3 Time Spent in Preparing and Filing Loan Applications

(Unit: Hours)

Chore	Small Farmers	Very Small Farmers	All Farmers
Completion of application form	1.21 (4.99) 19.01*	1.30 (5.76) 10.77*	1.26 5.37) 15.08*
Collection of documents and attestation of form	16.22* (66.86) 16.58*	15.25 (67.63) 19.41*	15.76 (67.18) 17.89*
Submission of application	6.83 (28.15) 28.99*	6.00 (26.61) 25.17*	6.44 (27.45) 27.95*
Total	24.26 (100.00) 14.80*	22.55 (100.00) 17.11*	23.46 (100.00) 16.07*

Figures in parentheses indicate per cent of the total.
*Value of coefficient of variation.

Time Costs

The time costs incurred by the sample farmers in completing the prescribed forms, collection of relevant documents and attestation of the forms, and submission of the applications for pumping set/tube-well loans are shown in **Table 3.**

There was not much difference in the time spent for preparing and submitting loan applications between the small and very small farmers. For preparing applications and submitting them to the SMFALA/Block Development and Panchayat Office, the small farmer spent an average of 24.26 hours as against 22.55 hours by the very small ones. The longest time was spent in the collection of documents and attestation of the form which accounted for 67 per cent of the total time spent by small farmers and 68 per cent by very small farmers.

The coefficient of variation (CV) in respect of the time spent in the completion of application forms was 19.01 for the small farmers and 11 for the very small farmers. There was relatively more variation in this chore within the small farmer category as compared with the very small farmer group. The CV for the time spent associated with the 'collection of documents and attestation of the form' was 16.58 and 19.41 for these farmers. These values for the cost relating to the submission of application were 28.99 and 25.17, respectively, which show high variation in both cases.

The 't' values were computed for studying the difference relating to each chore between the two farmer-groups. These values for the 'completion of the application form', 'collection of documents and attestation of the form', and 'submission of the application' were 0.60, 1.64 and 1.97 which were not significant at 5 per cent level.

Apart from the time spent by the farmers in the completion and submission of loan applications, they had to wait for a long time before the applications were processed, recommended and finally approved. The time taken by the Block Development and Panchayat Office, the SMFALA and the Land Mortgage Bank for disposing of the loan applications is indicated in **Table 4.**

The Bank entailed the highest percentage of the total time spent in processing the loan applications. It accounted for, on an average, 65 per cent of the total time in the case of a small farmers and 64 per cent for the very small farmer.

The CV for the time spent by the Block Development and Panchayat Office in processing the loan application was estimated at 23.14 for small and 34.41 for very small farmers.

The 't' values for the number of

Table 4 Number of Days Spent for Obtaining Loans

(Unit: Day)

Office	Small Farmers	Very Small Farmers	All Farmers
Block evelopment and Panchayat Office	5.92 (17.45) 23.14*	6.19 (18.58) 34.41*	6.55 (19.11) 26.72*
SMFALA	5.94 (17.51) 23.40*	5.88 (17.65) 38.27*	5.91 (17.24) 30.80*
Land Mortgage Bank	22.06 (65.04) 20.13*	21.25 (63.78) 23.48*	21.82 (63.65) 21.31*
Total	33.92 (100.00) 16.10*	33.32 (100.00) 17.92*	34.28 (100.00) 16.39*

Figures in parentheses indicate per cent of total.
*Value of coefficient of variation.

Table 5 Number of Visits Made by Loan Applicant to Various Offices

Institution	Small Farmers	Very Small Farmers	All Farmers
Block Development and Panchayat Office	1 (16.67)	1 (16.67)	1 (16.67)
SMFALA	1 (16.67)	1 (16.67)	1 (16.67)
Land Mortgage Bank	4 (66.66)	4 (66.66)	4 (66.66)
Total	6 (100.00)	6 (100.00)	6 (100.00)

Figures in parentheses indicate the percentage of total number.

Table 6 Costs of Applying for Loans

Cost Item	Small Farmers	Very Small Farmers	All Farmers
Fees for procuring documents	3.50 (3.66) 0.00*	3.50 (3.91) 0.00*	3.50 (3.78) 0.00*
Illegal gratification	62.50 (65.34) 17.62*	51.87 (57.92) 24.12*	57.19 (61.75) 22.29*
Travel expense			
a. Meals	13.46 (14.07) 18.87*	13.91 (15.53) 15.89*	13.69 (14.78) 17.24*
b. Transport	16.19 (16.93) 56.33*	20.28 (22.64) 33.63*	18.24 (19.69) 45.29*
Total	95.65 (100.00) 16.89*	89.56 (100.00) 12.48*	92.62 (100.00) 15.31*

Figures in parentheses indicate percentages of total.
*Value of coefficient of variation.

days spent by the Block Development and Panchayat Office, the SMFALA and the Bank for the small and very small farmers were 0.59, 0.13 and 1.07, all of which were not significant at 5 per cent level.

The borrower had to visit each of the Block Development and Panchayat Office and SMFALA once as compared to four visits to the Bank for pursuing their applications.

Expenditures

Table 6 shows that the total expenditures incurred by the small farmers for applying for the loan was Rs. 96 as against Rs.90 by the very small farmers.

The most important cost item was the illegal gratification which the farmers were compelled to pay to the officials for expediting the processing of their applications which represented 65 and 58 per cent of the total expenditure for the small and very small farmers, respectively.

Conclusions

The credit arranged by the SMFALA for pumping sets/tube-wells was sanctioned and disbursed by the Land Mortgage Bank partly in kind and partly in cash. Loans (both cash and kind contents) ranging from Rs. 3,700 to Rs. 4,700 or an average of Rs. 3,970 for small farmers and Rs. 3,967 for the very small farmers. The kind components of the loan comprised 49 and 50 per cent of the total loans secured by the farmers.

The time spent in preparing and submitting loan applications by small farmers was 24 hours and 23 hours for the very small farmers. The collection of documents and attestation of the application took the longest time. It took an average of 33 days for each group of farmers to receive their loans.

The expenditure incurred in making application and obtaining credit for pumping set/tube-well averaged Rs. 96 for the small farmer and Rs. 90 for the very small farmers. The most important cost item was the grease money for expediting the processing of documents.

These difficulties could, perhaps, be obviated by simplifying the procedure for making loan applications, reducing the number of documents and attestations required, and rationalizing the administrative procedure for dealing with the applicants files at various levels. ■■

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e. have a 50 to 100 word-abstract, preferably preceding the main body of the article ;
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   vi) bibliography
b. The pages must be numbered (Arabic numeral) successively at the top center. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e. g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top, center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e. g., "Figure 1. View of the Farm Buildings".
c. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
d. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
e. Express measurements in the metric system and crop yields in metric tons per hectare (mt/ha) and smaller units in kilogram or gram (kg/plot or g/row).
f. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
g. Convert national currencies in US dollars and use the later consistently.
h. Round off numbers, if possible, to one or two decimal units, e. g., 45.5kg/ha instead of 45.4762kg/ha.
i. When numbers must start a sentence, such numbers must be written in words, e. g., Forty-five workers . . . , or Five tractors . . ." instead of 45 workers . . , or, 5 tractors.

Effect of Parameters of Heat Balance Method Upon Irrigation Water Requirement of Cotton Plants

by
Md. Motiur Rahman Khan
Assistant Professor
Department of Irrigation & Water Management
Bangladesh Agri-Varsity
Mymensingh, Bangladesh

Abstract

This paper discusses the effects of parameters of heat balance method upon the irrigation water requirement of cotton plants. The loss of heat 'LE' due to evaporation depends upon the vegetative growing stages of cotton. Two years of field experimental results show that the minimum loss of heat 'LE' due to evaporation was 50, 110 and 75 percent of net heat radiation, 'R' during pre-flowering, flowering to formation of cotton bolls and during the period of maturation of cotton bolls, respectively. The cotton plant requires more irrigation water during the period of flowering to formation of cotton bolls than those of pre-flowering or maturation of cotton bolls.

Introduction

Several methods are available for estimating evapotranspiration. But most of the methods are largely empirical and require considerable local calibration (1). For hydrological research, it is desirable to use a method with a physical basis and which will provide daily evapotranspiration estimates with a minimum variation from actual evapotranspiration. Recently the heat balance method (2) has been developed with more or less accurate results (3). By this method it was found that at the time of application of irrigation water, the major portion of energy used for evapotranspiration is the exchangeable energy between the ground and air. The heat balance method consists of some components which have direct effects upon the irrigation water requirement.

Materials and Methods

The field research was conducted in Taskent, U.S.S.R with a Taskent – 1 variety of cotton during the vegetative growth period for determining the effects of parameters of the heat balance method. The method (4) can be expressed mathematically as:

$$LE = (R-Q-S)$$

or,

$$E = 1/60\,(R-Q-S) \text{ mm/minute}$$

where:

L = 60

E– = the evaporation, mm of water

R = the net radiative flux, cal/cm^2

Q = the sensible heat transfer to the atmosphere, cal/cm^2

S = the sensible heat transfer to the soil or other material cal/cm^2

The experimental field was 200 meters long and 120 meters wide. All experimental apparatus for this method were placed at the centre of the field for recording the required data (5).

The data were recorded every 4 hours throughout the whole vegetative growing seasons (from April to September) of the cotton plants. The value of the parameters LE, R, Q and S of this method were calculated for every 10 days and just after and before application of irrigation water.

Results and Discussion

The evapotranspirations were estimated by changing the parameters LE, R, Q and S of the

heat balance method and the quantity of irrigation water were estimated on the basis of soil moisture method. The value of parameters and the quantity of irrigation water are shown in the **Table 1**.

During the month of May the average radiative flux R was less and was 352 cal/cm^2 day. Due to sufficient soil moisture present in the soil, no irrigation was required during this period. The radiative flux R was not high at the beginning of the vegetative growth period of cotton. The radiative flux R increased with the growth of cotton and reached a peak value of 436 cal/cm^2 day during the middle of July. The greatest volume of irrigation water (138 mm) required corresponds to this period. After reaching the peak, the value of R gradually decreased (337 cal/cm^2 day) at the end of the vegatative growing season of cotton. During the whole growing season the total amount of evapotranspiration was 701 mm and total amount of irrigation water was 695 mm. The evapotranspiration E, heat loss due to evaporation LE and net radiative flux R throughout the whole growing season. Irrigation water depends on the amount of evapotranspiration E, loss of heat due to evaporation LE and net radiative flux R. The value of these parameters are maximum during flowering to formation of cotton boll period. Heat loss due to evapotranspiration LE, was 50, 110 and 75, percent of net radiation R during pre-flowering, flowering to formation of cotton boll and during the maturation of cotton bolls, respectively.

Irrigation is one way to create a favorable condition for crop growth. By applying irrigation water the parameters of the heat balance method changes. The comparative values of the parameters before and after irrigation are shown in **Table 2**. At the beginning of the vegetative growth period the radiative flux R increased 10–20 percent after irrigation due to the decreases in soil temperature.

Irrigation water largely depends

Table 1. Value of Parameters of Heat Balance Method Every 10 Days

Month	Duration	Net Radiative Flux, R, Cal/cm^2 Day	Sensitive Heat Transfar to		Loss of Heat due to Evaporation LE, Cal/cm^2 Day	Evapotrans-E, mm.	Quantity of Irrigation Water (on Soil Moisture Basis) M, mm.
			Atmosphere, Q, Cal/cm^2 Day	Soil or Other Surface Material S, Cal/cm^2 Day			
May	II-ten days	343	56	93	194	36	–
	III-ten days	361	48	87	227	42	–
June	I-ten days	395	64	54	278	46	–
	II-ten days	414	32	36	346	58	83
	III-ten days	429	40	–13	401	67	130
July	I-ten days	446	23	–52	455	76	–
	II-ten days	436	31	–59	466	78	138
	III-ten days	420	24	–25	422	77	132
August	I-ten days	418	21	–28	415	71	122
	II-ten days	338	15	–42	366	61	90
	III-ten days	306	30	59	277	51	–
September	I-ten days	307	23	76	240	38	–

Table 2. Value of Parameters of Heat Balance Method Just Before and After Irrigation

No. of Irrigation	Type of Observation	Net Radiative Flux R, Cal/cm^2 Day	Sensitive Heat Transfer to		Loss of Evaporation, LE, Cal/cm^2 Day	Loss of Evaporation, LE, Cal/cm^2 Day (percent)
			Atmosphere, Q, Cal/cm^2 Day	F Soil Surface, S, Cal/cm^2 Day		
1	Before Irrigation	410	30	42	338	13.6
	After Irrigation	420	32	4	384	
2	Before Irrigation	425	38	–12	399	7.5
	After Irrigation	434	40	–35	429	
3	Before Irrigation	420	25	–51	446	3.9
	After Irrigation	435	28	–56	463	
4	Before Irrigation	410	22	–54	442	2.8
	After Irrigation	418	24	–60	454	
5	Before Irrigation	416	18	–30	428	2.1
	After Irrigation	422	21	–36	437	
6	Before Irrigation	340	12	–40	368	1.9
	After Irrigation	344	15	–42	375	

Fig. 1 Calculated, E, parameters of heat balance method and amount of each irrigation for cotton.

on the evaporation and sensible heat transfer to the atmosphere Q. Evaporation was highest (13.6%) at the beginning and then gradually decreased at the end (1.9 percent). The loss of heat due to evaporation increased after irrigation. The value of sensible heat transfer to the soil S decreased and gradually became negative. No heat was transferred from the soil after irrigation. Heat from the upper layer of the soil comes from the atmosphere.

Conclusion

The determination of evapotranspiration in cotton plants is very important when applying irrigation water during the growing season. The heat balance method is one of the reliable methods for determining the evapotranspiration. This method can be calculated at any time for a large area. Besided this, the parameters of this method have important functions on water requirement of cotton crop. The changeable heat transfer within the soil and atmosphere which is very important before and after irrigation can be determined following this method.

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Estimation of Ground Recharge in a Basin Water Balance Study

by
L. R. Khan
Assistant Professor
Department of Irrigation & Water Management
Bangladesh Agricultural University
Mymensingh, Bangladesh

Tawatchai Tingsanchali
Associate Research Professor

Anat Arbhabirama
Professor & Chairman
Division of Water Resources Engineering
Asian Institute of Technology, Bangkok, Thailand

Abstract

Estimate of groundwater recharge in a basin can be performed from a water balance study. In a book-keeping method, the elements of the balance equation should be calculated on monthly basis. The major elements of the equation are comprised of rainfall, streamflow, evapotranspiration, sub-surface underflow, surface water, soil moisture and groundwater storages. The rainfall and streamflow data can be collected from a number of representative stations of the basin. Imported and exported water to and from the basin are to be included in the computation. Potential evapotranspiration values can be computed from climatological data and a suitable method must be selected for the basin based on class A pan evaporation. Actual evapotranspiration and soil moisture storage should be computed using the Thornthwaite-Mather hypothesis.

The computation should be performed by providing monthly hydrological inputs for the desired period. The monthly groundwater recharge and change in groundwater storage can be obtained by this method. The average groundwater recharge to the basin will be found as output by averaging the former values. Depending on the availability and quality of necessary inputs, this method will provide a reliable estimate of groundwater recharge in any basin.

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Introduction

Groundwater is one of the earth's most widely distributed and important renewable resources. It constitutes one of the major portions of the earth's water circulating system known as the hydrologic cycle. Groundwater exists where-ever water penetrates beneath the surface and becomes a usuable resource when the rocks in the zone of saturation are permeable enough to yield useful supplies of water to wells, springs or streams. Recharge rates for aquifers in a basin must be estimated before groundwater resources can be evaluated. In many places, the major sources of recharge to aquifers are direct precipitation on intake areas and/or downward percolation of stream runoff. Only a small fraction of the annual precipitation percolates downward to the water table. A large portion of precipitation runs overland to streams or is discharged by the process of evapotranspiration before it reaches aquifers. The amount of precipitation that reaches the zone of saturation depends upon several factors (Walton, 1970).

Estimation of potential recharge to a groundwater basin can be made by simplified solutions of the equation of hydrologic equilibrium or water balance. The general equation for water balance is a quantitative statement of the balance between the total water gains and losses of a basin for a period of time. This balance considers all waters, surface and subsurface, entering and leaving or stored within a basin. Water entering a basin is equated to water leaving a basin, plus or minus the changes in basin storages. Under specific conditions, precipitation is the source of water entering the basin and is the only water gain considered in the water balance study. Water leaving the basins includes stream flow, evapotranspiration and subsurface underflow. The storages belong to soil moisture, groundwater and surface water. There are many situations in which several items of the general water balance equation can be eliminated because they do not measurably affect the balance between water gains and losses.

In this paper attempts have been made to indicate a procedure for estimating groundwater recharge in a basin by simplified solutions of

water balance equation. This will be useful in making preliminary evaluations of groundwater resources of a basin for providing optimum utilization and management of aquifers.

Water Balance Equation

A water balance is an accounting of the water gains and losses of a river basin over a certain period. Rainfall occúring over the river basin is assumed to be disposed of as stream flow, evapotranspiration, change in surface water storage, change in soil moisture storage, change in groundwater storage, and groundwater recharge.

This may be expressed by a Mass conservation equation as

$$P = SF + AE + \Delta SW + \Delta SM + \Delta GW + GRC \quad \ldots\ldots\ldots (1)$$

where, P is the equivalent uniform depth of rainfall over a river basin,

SF is stream flow from the basin,

AE is actual evapotranspiration,

ΔSW, ΔSM and ΔGW are the changes in surface water, soil moisture and groundwater storages, respectively, and GRC is the groundwater recharge.

For a long-term average annual water balance computation, the long-term average of the annual changes in the storages are small and can be neglected. So, equation (1) becomes –

$$P = SF + AE + GRC \quad \ldots\ldots (2)$$

If there exists extra import of water to or from the basin, equation (1) becomes –

$$P + I = SF + AE + \Delta SW + \Delta SM + \Delta GW + GRC + Q_o \quad \ldots\ldots\ldots\ldots (3)$$

where, I and Q_o are imported and exported water to and from the basin, respectively.

The monthly water balance computation can be prepared through a number of years with the help of Equation (3). The long-term average annual water balance computation is obtained from the results of the monthly water balance computation.

Groundwater Recharge

Groundwater recharge is that part of the rainfall which percolates deep through the soil to the confined aquifers. During rainy season, a part of infiltrated rains move down and satisfy the soil moisture deficiency and groundwater storage before discharging through the aquifers.

Neglecting exported water and change in surface water storage in the basin, groundwater recharge can be estimated from equation (3) as –

$$GRC + \Delta GW = P + I - SF - AE - \Delta SM$$

For a number of years, the above water balance equation can be expressed as –

$$\sum_{j=1}^{n} \sum_{i=1}^{12} GRC_{ij} + \sum_{j=1}^{n} \sum_{i=1}^{12} \Delta GW_{ij} = \sum_{j=1}^{n} \sum_{i=1}^{12} (P_{ij} + I_{ij} - SF_{ij}\ AE_{ij} - \Delta SM_{ij}) \quad \ldots\ldots\ldots\ldots (8)$$

where, j is the number of years over the n years, and i is the number of a month in the year.

Considering $\frac{1}{n} \sum_{j=1}^{n} \sum_{i=1}^{12} \Delta GW_{ij} = 0$, the average annual groundwater recharge $\overline{GRC}$, can be estimated as –

$$\overline{GRC} = \frac{1}{n} \sum_{j=1}^{n} \sum_{i=1}^{12} GRC_{ij} = \frac{1}{n} \sum_{j=1}^{n} \sum_{i=1}^{12} (P_{ij} + I_{ij} - SF_{ij} - AE_{ij} - \Delta SM_{ij}) \quad \ldots\ldots\ldots (9)$$

Procedure of Study

The water balance computation is performed on a monthly basis for the basin. The results of monthly water balances are then summarized in terms of the long-term average of each month in a year. From these results the long-term average annual balance is then deduced. The following is the chronological computational procedure of the monthly water balance computation for estimating groundwater recharge. The numbers in the block figures as shown in **Fig. 1** refer to the steps of procedure.

1. The mean monthly rainfall over the river basin is computed from the monthly rainfall data using the Theissen or Isohyetal method.

2-3. The potential evapotranspiration is then computed from a suitable method for the basin by using climatic data such as temperature, humidity, sunshine duration, empirical crop factors, etc.

4. Knowing the type of soil and crops, the maximum soil moisture storage is determined from the Table as given by Thornthwaite & Mather (1957, 1955).

5. Knowing the rainfall, potential evapotranspiration and soil moisture, the actual evapotranspiration is computed.

6. The stream flow at the outlet of the river basin is converted to the uniform depth with respect to the basin area.

7. Imported water to the river basin should be included in the computation. The imported water to the basins is mainly from the outflow of the adjacent basins. The difference between the stream flow and the imported water can be referred as the effective outflow.

8. From the water balance equation as expressed in Equation (3), the monthly groundwater recharge and change in groundwater storage are determined.

9. The computation is perform-

Fig. 1 Steps in water balance computation

ed month to month over the years until the desired period is covered. The monthly groundwater recharge and change in groundwater storage are accumulated and annually averaged to obtain the long term average groundwater recharge to the basin.

Recharge at the Upper Chao Phraya River Basin (Thailand)

The water balance computation was performed for the Upper Chao Phraya River Basin to estimate groundwater recharge. The mean monthly water balance was computed by two different ways as follows:

1. The monthly water balance was performed continuously from April, 1965 to March, 1973.

2. The mean monthly water balance was computed directly from the mean monthly rainfall, streamflow and climatic data, etc. from 1965 to 1973.

The results obtained from both methods were compared and found to agree closely (Khan, 1976) as shown in **Fig. 2**. The mean annual water balance for this river basin was computed from the mean monthly water balance. The result of the mean monthly water balances of the basin is shown in **Table 1**. In this computation the long-term average annual changes in the surface water storage and groundwater storage were negligible. The long-term average annual groundwater recharge to this river basin was determined using Equation (9) which amounted to 9099.5 $\times 10^6$ gal/day or about 9 per cent of the total rainfall over this basin.

Discussion

The water balance method of estimating groundwater recharge requires an extensive data collection within the basin. Lack of adequate data is a limiting factor in the study. Consequently, the method of computation presented here is based on some simplifying some assumptions which may vary from basin to basin.

The actual evapotranspiration is computed by using data on rainfall, potential evapotranspiration and soil moisture storage. The maximum soil moisture storage as given by Thornthwaite and Mather (1957) is based on types of soils and vegetation. There are variations in maximum soil moisture capacity, average and mean soil moisture storages for the basins. This may be due to differences in soil conditions, types of vegetation and cropping pattern.

Table 1. Average Monthly Water Balance for the Upper Chao Phraya River Basin, Thialand

Month	Rainfall (mm.)	Evapo-transpiration, (AE in mm.)	Effective Outflow (mm.)	Storage, SM Storage, (SM in mm.)	Groundwater Recharge plus Change in GW Strage GRC + AGW (mm.)
January	8.11	47.13	5.83	100.75	+ 3.33
February	6.39	33.68	4.65	66.25	+ 2.55
March	34.86	5.51	55.86	37.50	+ 2.34
April	61.80	80.47	5.19	41.25	−16.24
May	193.79	130.33	7.27	104.50	− 7.06
June	141.80	97.13	11.59	144.87	− 6.60
July	159.00	97.69	15.45	192.25	− 2.70
August	234.36	85.29	25.11	230.37	+85.69
September	201.73	73.40	41.56	250.00	+67.14
October	113.34	79.85	44.58	427.50	− 8.59
November	26.77	65.61	20.76	199.87	−11.98
December	12.73	55.11	10.07	149.00	− 2.65
Mean	1194.68	901.55	197.59	–	+105.23

Fig. 2 Average monthly water balance for the upper Chao Phraya River Basin

The long-term average annual changes in the equivalent uniform depth of the surface water storages for the river basins are insignificant in the water balance computation due to periodic fluctuation in the surface water levels.

In this study imported water is considered to consists of stream flow only. The trans-basin groundwater recharge and lateral inflow from outside the aquifer in the basin have been disregarded.

The groundwater storage and groundwater recharge to the aquifers of the basin cannot be evaluated separately due to lack of accurate information on the fluctuation of groundwater storage. The long-term annual average of the change in groundwater storage, however, approaches zero. From this condition groundwater recharge to the basin can be determined from a long-term water balance computation.

Conclusion

Estimate of recharge to the groundwater basin has been evaluated in this paper. The method for evaluating the groundwater recharge by water balance computation is, of course, not very refined but it is the most detailed method that could be attempted given the time and accurate hydrological inputs. It should be noted that the water balance computation could give only approximate estimation of groundwater recharge since groundwater recharge accounts only for a small percentage of rainfall, evapotranspiration and streamflow could, therefore, introduce a large error in the estimation of groundwater recharge.

An estimate of the availability of groundwater to the Upper Chao Phraya River Basin was carried out by applying this method. The groundwater recharge was found to be 8099.5 X 10^6 gal/day. It seems that this simplified model works reasonably well under the prevailing conditions. However, in order to apply this method for estimating groundwater recharge to any basin, a logical step would be to improve its accuracy and adopt it for a computer for facilitating calculation. Hence, it can be concluded that the standard procedures of evaluating the water balance for estimating groundwater recharge should be modified to fit local conditions, taking into account the availability and quality of input data as well as special features of the basin.

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Effects of Moisture Content on Quantitative and Qualitative Losses in Wheat

by
Bilash Kanti Bala
Associate Professor

Md. Daulat Hussain
Assistant Professor

S.M. Hossain Saif
Assistant Professor

Md. Iqbal Hussain
Assistant Professor

Department of Farm Power & Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh

Abstract

This study determined the effects of moisture content on quantitative losses (harvesting and threshing), milling quality and nutritive value of wheat. The loss was influenced by the moisture content. Milling quality and nutritive value were independent of the moisture content during harvesting.

Introduction

Wheat is the second most importants food crop in Bangladesh. The cultivated area covered by wheat is increasing rapidly. In this context, it is also significant to note that the UN Seventh General Assembly passed a bill to reduce wheat post-harvest losses to 50 percent by 1985. Several high yielding varieties have already been developed and introduced throughout the country. Toquero et. al. (1977) investigated the quantitative and qualitative losses of rice in the Philippines by using scientific methodology. Also, Ojha et. al. (1975) studied the effects of moisture content on post-harvest losses of rice and they have suggested that an optimum harvesting period for Joya paddy for maximum grain yield per hectare as well as for superior milling quality.

This study was undertaken with the following objectives:

a) To study the effect of moisture content on post-harvest losses of wheat (harvesting and threshing loss).

b) To study the effect of moisture content during harvesting on size reduction of wheat.

c) To assess the effect of moisture content during harvesting on nutritive value of flour.

Materials and Methods

The experiment was conducted at Agricultural Farm of Bangladesh Agricultural University, Mymensingh, Bangladesh. The experimental design was a completely randomized block with six treatments replicated four times using 2 X 2 m plots. Four systems involving alternative combinations of technology and management utilized are shown in **Table 1**. The area of fields selected for each system was carefully measured and recorded. The selected fields had the same soil conditions. In addition uniformity of variety was ensured and sowing was completed in one day (November 20, 1978).

Following the harvesting, grains that had either fallen on the ground or remained unharvested within sample area were hand picked and weighed. This process was replicated four times. To measure handling and stacking losses, materials harvested were moved to the farm yard and stacked on concrete floor. Following the stacking operation, grains remaining on the floor were weighed. To measure the threshing losses incurred by using traditional and mechanical (pedal thresher designed in the Department of Farm Power & Machinery, **Fig. 2**) system, re-threshing and hand picking were employed. This process was repeated for different

Table 1. Alternative Combinations of Technology and Management

System	Harvesting	Handling and Threshing	Drying	Milling
1	Traditional	Traditional	Traditional	Commercial
2	Traditional	Traditional	Mechanical	Commercial
3	Traditional	Mechanical	Traditional	Commercial
4	Traditional	Mechanical	Mechanical	Commercial

Fig. 1 Wheat experimental field at BAU Farm

Fig. 2 Threshing of wheat by pedal thresher

moisture content.

Losses in post production systems of wheat were measured as follows: Grain samples for different systems were dried by traditional and mechanical methods. Then replicated samples were milled and the fineness modulus was determined. This process was repeated for different systems to assess the effect of moisture content on fineness modulus of wheat flour. These flour samples were again replicated for each system and tested to assess the effect of moisture content on the nutritive value of the samples.

Results and Discussion

Effect of moisture content on harvesting and threshing losses

A major portion of wheat grains are lost during the harvesting and threshing processes. Handling and stacking losses are usually negligible. **Table 2** shows the harvesting and threshing losses for different moisture contents.

Fig. 3 Relationship between harvesting and threshing losses and moisture content

Table 2. Wheat Harvesting and Threshing Losses

Date of Harvesting	Moisture Content (Percent)	Harvesting and Threshing Losses (Percent)	
		Traditional (Manual)	Mechanical (Pedal Thresher)
Feb. 27, 1979	50.05	27.23	17.19
March 2, 1979	46.43	18.03	12.48
March 5, 1979	30.46	12.18	7.72
March 8, 1979	17.49	10.77	6.22
March 11, 1979	17.98	9.13	9.75
March 14, 1979	15.47	4.09	7.25

The relationship between harvesting and threshing losses and moisture content was linear for each method (**Fig. 3**). It appears that a break-even point is reached at about 16 percent moisture content below which grain losses seem to be greater for mechanical threshing due to the overdry condition of stalks which were crashed before the grains could be separated from the ears. And this was obviously due to the improper design of the threshing cylinder of the thresher. Therefore, this kind of grain loss could be overcome by improving the threshing unit compared. The mechanical method shows a reduced tendency in threshing loss, due to the low efficiency of the pedal thresher. Thus, losses in threshing can be reduced by improving the pedal thresher.

Effects of Moisture Content

The harvested wheat grains through various methods were dried to a standard moisture content (15%) level. After milling in a commercial wheat grinding mill, the fineness modulus was determined by sieve analysis (Henderson & Perry, 1976) the result of which is shown in

Table 3. Fineness Modulus of Wheat Flour

Moisture Content at Harvest Time (Percent)	Fineness Modulus of Different Systems			
	1	2	3	4
50.05	0.57	0.66	0.54	0.52
46.43	0.63	0.48	0.32	0.61
30.49	0.58	0.58	0.45	0.56
17.49	0.47	0.56	0.56	0.57
17.98	0.59	0.58	0.64	0.39
15.47	0.31	0.51	0.41	0.63

Table 4. Analysis of Variance for Fineness Modulus

Source	d.f	S.S.	M.S.	F	5% F
System	3	0.02	0.0066	0.62	3.29
F.M.	5	0.03	0.0060	0.57	2.90
Error	15	0.16	0.0106	–	–
Total	23	–	–	–	–

Table 5. Protein Content (Percent)

Moisture Content at Harvest Time (Precent)	Protein Content (Percent) of the Systems			
	1	2	3	4
50.05	12.41	12.05	12.13	12.22
46.43	12.14	12.22	13.57	12.40
30.49	11.69	11.51	14.81	12.35
17.49	12.09	12.69	12.23	12.67
17.98	14.82	12.95	13.12	12.50
15.47	12.05	12.13	13.66	12.22

Table 6. Analysis of Variance for Protein Content (%)

Source	d.f	S.S.	M.S.	F	5% F
System	3	2.83	0.566	1.31	2.905
Protein content	5	7.49	2.49	0.579	3.29
Error	15	6.39	0.43	–	–
Total	23	–	–	–	–

Table 3. An analysis of variance of the data in **Table 3** is shown in **Table 4.** There was no significant difference among the systems at 5% confidence level. As well as in the fineness modulus at different moisture contents during harvest.

After milling, the wheat flour was kept in sealed polyethylene bags. Protein content was determined at the Department of Bio-Chemistry, Bangladesh Agricultural University. **Table 5** shows the protein contents (percent) for different systems. An analysis of variance for protein content is shown in **Table 6.** There is no significant difference among the systems and among the protein contents at 5% confidence level for different moisture content at harvest period.

Post-harvest losses in wheat can be reduced by harvesting at lower moisture content and by designing a more efficient pedal thresher.

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Development and Evaluation of a Simple Tractor-Mounted Digger for Sugar Beet

by
Tara Chandra Thakur
Assistant Professor

Raj Deo Singh
Research Fellow

Bachchan Singh
Associate Professor

Department of Agricultural Engineering, G.B. Pant University of Agriculture & Technology, Pantnagar-263145 (U.P.), India.

Introduction

Sugar beet is a new sugar crop in India. Basically, it is considered to be a crop of the temperate region but its cultivation is spreading to subtropical areas of the world also. More than 45 percent of the world sugar requirement is met from sugar beet[1]. In the past very little effort has been put towards the mechanization of sugar beet production and most of the farm operations are still traditional. Harvesting sugar beet in Northern India extends from late March until late May which coincides with that of wheat. Traditionally, sugar beet is harvested manually with the use of manual spade (**Fig. 1**) which requires about 325 man-hours per hectare. Since during this period there is scarcity of labour due to harvesting of wheat, the supply of beets to the factory is interrupted. In recognition of this problem a suitable sugar beet digger was developed especially for small farm holdings.

Fig. 1 Harvesting of beats by spade

The cost of harvest by manual method is about 13 percent of the value of the crop and the overall losses through manual labour averages from 4 to 4.5 percent[2] Many farmers use tillers and sometimes furrower blades for digging the beets. In both cases the percent damage is high and recovery is poor. In addition to this, the use of furrower leaves the ground undulated which needs a separate operation for levelling. A number sugar beet combine harvesters are in use in developed countries but these are expensive and suitable for large holding. Keeping in view the above factors, a simple two-row tractor-mounted digger was developed and evaluated for its performance.

Previous Studies

Sugar beet combines consist mainly of four units, i.e., topping, lifting ploughs, conveying, cleaning and loading to the trailers.

A common type of lifting device is a pair of triangular shares having an inclined upper surface and splayed to exert pressure on the soil at each side of the beet. In another type of lifting device, two slightly concave, splayed wheels are rotated by ground contact to give a more positive lifting action. The rotation of the wheels reduces the draft of the machine, and the higher beet discharge point and corresponding elevator position results in less soil and trash being taken up the elevator. Although steering accuracy is important with either type of lifting device, it is more critical with wheels than with shares.

Hipple[3] reports a prototype international sugar beet harvester which harvests one acre of beets every 2.5 hours. After the test runs, some modifications were incorporated in the harvester, mainly, a floating top flinger drum, heavier chain drive and the inclusion of a master slip clutch on the belt pulley shaft as an overload

protecting device for all moving parts. However, the problem of mechanical clod separation was still with the machine. Urschel[4] reported a combine harvester pulled along the rows of beets, with a one-pointed lifting plough extending about 12 inches into the soil below the beets. The harvester operates at about 3 to 4 mph for good results. Guelle[5] reported a McCormic-Deering harvester which performs topping, lifting, cleaning, loading and transporting the beets to the edge of the field in one continuous operation. It consists of the harvester units mounted on the right-hand side of a tractor and a self-unloading, two-wheel tank cart pulled behind the tractor. The beets are lifted from the ground by two lifter blades. Two 16-inch notched rolling coulters are mounted directly ahead of the puller blades which cut the trash and reduces the size of clods which aided in proper cleaning of the beets.

John[2] developed a sugar beet harvester consisting mainly of topping, ploughing, root elevation and root disposal units. He tried a pair of conventional beet-lifting plough used in loosening the beets for manual harvest. The blades are operated along either side of the beet row at a depth of about 7 inches. However, this type of plough was found unsuitable for mechanical harvesting in many ways: it had little off-row tolerance which strikes the beet by the leading edge of the plough blade before it is loosened. Moreover, a broken tap root was the usual result and the remaining portion of the beet was likely to roll out of position before it could be grasped by a pick-up device. It also failed to loosen the small beets in wet soil. A helical plough was further developed for mechanical harvesting which was superior to conventional lifters in clod size reduction and increased off-row tolerance.

Prochazka[6] studied the force and power relationships of some types of lifting tools (fixed shares and lifting wheels) as affected by forward speed and working depth. It was observed that over the forward speed range of 1.0–2.0 m/s the draft increased with shares having a negative cut angle. The draft and drive power increased very rapidly with working depth. The peripheral speed of the driven lifting wheels did not effect the draft but only the driving power. From optimum angle of conversion the lifting wheels in horizontal plane were kept at 25–30 degrees. The minimum gaps between the wheels was kept at 40 mm.

Srivastava[7] et al developed a three-row tractor drawn sugar beet digger and used sweeps as lifting shovels. Spacing between shovels was maintained at 150–200 mm. It was reported that about 98.80 percent of the roots were uprooted at proper moisture content and the damage through cuts to the beets was about 1 percent.

Construction Details

The sugar beet digger is essentially a simple device for digging two-rows of beets at a time. It consists of a frame of 1500 X 75 X 75 mm made from two angle iron pieces by welding them together. A number of holes (12 mm diameter) were drilled at a distance of 25 mm for adjustment of the spacing between two shovels. Two pairs of mild steel flats 50 X 15 mm were forged and twisted at the centre to reduce the size to 25 X 25 mm at the tip and to make an angle of about 40 degree with the vertical plane. The lower end of the standard was provided with two holes for mounting the shovels. The twist in the centre of the standard gave extra strength against bending (Fig. 2). While in operation, each

Fig. 2 Sugarbeet digger design

pair of standard is positioned at the side of the sugar beet row. The top of the standards was welded to the mild steel flats, having four holes each and were mounted with the frame by nuts and bolts. Arrangements were provided for mounting the digger on three-point linkage of the tractor.

Materials and Methods

The digger was developed in 1978 and was used over an area of about 50 hectares on farmers' fields with encouraging results. However, the trials were conducted in the months of April-May 1979 on an area of about 30 hectares available in the nearby Kichcha sugar mill, about 15 km away from the G.B.Pant University of Agriculture and Technology, Pantnagar. The tests were conducted on the Ramonskaya variety of sugar beet which is commercially grown in this area. At the time of sowing, the ridges were formed by a tractor-drawn ridger at a distance of 500 mm and the seeds were sown by dibbling. The details of the size of the beet, spacing etc. are shown in **Table 1** for the test plots. Prior to digging of the beets, soil samples were collected from different locations of the test area at depths ranging from 0 to 150 mm and the moisture content was determined by the oven dry method. The compaction of the soil was also measured by a cone penetrometer. The soil samples were analysed by sieve analysis method and was noted as silty-clay-loam type. Three types of shovels, namely; duck foot, double pointed, and sweep types were used to evaluate their performance at various speeds **(Fig. 3)**. The digger was operated by a 25 hp tractor at different average speeds of 2.20, 3.10, 4.30 and 5.4 km/hr. In the test plot, an area of 90 X 24 meters was marked to carry out the tests.

Fig. 3 Different type of shovels

Before the test run, the spacing between the pairs of shovels was adjusted at 200 mm and the depth was maintained at 100–150 mm below on both side of the ridge. For each shovel at a selected speed, 4-rows of 90 meters long were harvested and the samples were collected from an area of 6 X 2 meters at three different places. The weights of undamaged, quarter damaged, unremoved beet, and the cut beets and left in the field were noted separately and the percentage contribution of each item was recorded.

There are two distinct methods which are common in digging the beets by manual labour. In one method, the beets are first topped and then harvested by manual spade while in the second method, the beets are first harvested and then topped **(Fig. 4)**. Preliminary tests were carried out by the digger for both the methods of dig-

Fig. 4 Topping of beets after harvesting

Fig. 5 General view of pulling beets by hand

Table 1. Various Soil and Crop Parameters for Test Plot

Replications	Soil Moisture Content at Depth, cm (%)			Compactness of Soil	Average Working Depths Shevel	Spacing between Beets	Average Length of Beets	Average Diameter of Beets
	0-5	5-10	10-15	(kg/cm²)	(cm)	(cm)	(cm)	(cm)
I	3.2	12.4	14.1	2.4	12.0	20.5	25.5	8.9
II	9.3	11.9	13.7	2.5	14.0	22.0	26.7	9.05
III	8.9	13.2	14.5	2.3	12.5	21.6	28.0	8.6

ging and topping. It was noted that in the first method the topped leaves were gathered at the shovels and it was not possible to carry out the tests. Hence, the second method was adopted for the purpose. In this method the beets were loosened in the soil and then pulled out by manual labour very easily (**Fig. 5**).

Results and Discussion

The effect of speed on the performance of three types of shovels used on digger are presented in **Table 2**. The recovery for shovel A, B and C at different speeds varied from 80.00–98.95, 88.10–99.75 and 84.20–97.25 percent, respectively. This shows that shovel B performed better in respect of percent recovery followed by shovels A and C. In the case of shovel B, the depth of penetration was maximum due to its pointed edge. Moreover, the maneuverability of the tractor was much better resulting in high recovery of beets even at higher speeds. It may be noted from **Fig. 6**, that for all types of shovels the percentage recovery decreases with an increase in speed but at a speed of 3.10 km/hr, the recovery was maximum. The reduction in the recovery of beets at higher speed may be due to more percentage of beets left in the field unremoved caused by difficult control on steering of the tractor.

Fig. 6 Percent recovery of beets for three types of shovel at different speeds

On cut beets, only the quarter portion from the bottom side were damaged (**Fig. 7**). The percentage damage varied from 1.50–10.20, 0.50–5.70, and 1.05–12.80 for shovels A, B and C, respectively. The damage for shovel B was minimum at all speeds because of its full penetration in the soil. There was only 0.50 percent damaged beets at the speed of 3.1 km/hr for shovel B, followed by shovel A (1.5%), and shovel C (3.5%), respectively. The high percentage of damage for shovel C was due to poor penetration into the soil.

The 1/4th bottom portion of the beets which were cut and left in the field were considered as loss. The percentage losses for all type of shovels at various speed is shown in **Fig. 8**. The percentage loss increased with speed for all types of shovel.

Considering the percentage of beets not removed by the shovels it

Table 2. Effect of Speed on Performance of Various Types of Shovels Used on Digger

Type of Shovel	Average Speed, km/hr	Beet Removed: Undamaged percent	Beet Removed: 1/4th Damaged (Percent)	Beet Removed: Percent Recovery	Beet Not Removed Percent	Losses (Percent)	Capacity* (ha/day)
Shovel A (Duck Foot Type)	2.2	96.30	–	96.30	3.70	–	1.58
	3.1	97.45	1.50	98.95	1.05	0.70	2.23
	4.3	30.10	6.20	86.30	10.70	2.25	3.10
	5.4	69.80	10.20	80.00	20.00	4.82	3.89
Shovel B (Double Pointed Type)	2.2	98.20	–	98.20	1.80	–	1.58
	3.1	99.25	0.50	99.75	0.25	0.20	2.23
	4.3	89.85	2.50	92.35	7.65	1.20	3.10
	5.4	82.30	5.80	88.10	11.90	3.00	3.89
Shovel C (Sweep Type)	2.2	92.45	1.05	93.50	6.50	0.40	1.58
	3.1	94.00	3.50	97.50	2.50	1.75	2.23
	4.3	80.00	9.60	39.60	10.40	3.95	3.10
	5.4	71.40	12.80	84.20	15.80	6.50	3.89

* Capacity at 90 percent field efficiency and 8 hours work per day.

Fig. 7 View of undamaged and quarter-damaged beets

Fig. 8 Effect of speed on beet losses for three types of shovel

is clear that at the speed of 3.1 km/hr the percentage unremoved is minimum for all the shovels. At a lower speed of 2.2 km/hr the loosening of soil around the beets was less which left many of the beets unremoved.

Conclusions

1. The double pointed shovel was the best shape among the duckfoot type and sweep type shovels.
2. The digging speed of 3.1 km/hr was the best out of four speeds used in the test.
3. The maximum damage to the beets was 3.5 percent for the sweep type shovel whereas the minimum damage was 0.50 percent with the double pointed shovel at the best speed.
4. The recovery of beets was maximum at 99.75 percent for the double-pointed shovel whereas it was minimum at 97.50 percent for the sweep type shovel at the best speed of 3.1 km/hr.
5. Beet loss was minimum at 0.20 percent for the double-pointed shovels whereas it was 0.70 percent for the duckfoot type and 1.75 percent for sweep type shovels at the best speed.

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Traction Potential of Pneumatic Tire for Tractors

by
M. A. Khan
Senior Scientist
Water and Soil Engineering
Central Arid Zone Research Institute
Jodhpur (Rajasthan), India

Irshad Ari
Associate Professor
Department of Agricultural Engineering
Allahabad Agricultural Institute
Allahabad (U.P.), India

Abstract

The experiment was conducted at the Allahabad Agricultural Institute, Allahabad to test the Beaver Tractor Tire in varying drawbar pull and wheel weights on concrete surface at a constant rotating speed of the tire. Increase in drawbar pull increases slippage and at the same time linear speed decreases. On the concrete surface the drawbar horse power is directly proportional to drawbar pull. Therefore, increases in drawbar pull increases the drawbar horse power.

Introduction

Since 1936 rubber tires have replaced the lug and spades. Rubber is approximately 30% more efficient and has made possible tractor use on the road with comfort. A pneumatic tire has an advantage over the steel wheel in fuel consumption at the higher · speed along with maximum drawbar horse power. At present, almost all agricultural tractors are equiped with rubber tires.

The tractive efficiency of these pneumatic tires is very low, particularly in field condition where soil is loose and high tractive effort is required rather than speed. In order to have maximum output from the tractor in field condition, it must have high tractive efficiency. To improve the tractive efficiency, the entire aspect of traction has to be throughly investigated.

The project "Traction Potential of a Pneumatic Tire" was undertaken at the Allahabad Agriculture Institute, Allahabad to test the Beaver Tractor Tire in the laboratory with varying drawbar pull, and wheel weights on concrete surface at a constant rotating speed of the tire.

Review of Literature

Hardy reported that with pneumatic tires an increase load resulted in a decrease in linear speed and increase in drive wheel slippage. The drawbar hp also increased with an increase in load.

Ojha noticed that the performance of the pneumatic tires was better than that of the steel wheel in Kharagpur soil. The pull Vs slip curves were steeper in the initial stage for the rubber tire than for the steel wheels. This shows the tendency of a better grip between pneumatic wheel and the soil at lower value of slip.

Materials and Methods

Suspension Unit

The main function of a suspension unit is to support the prime mover and power transmission unit as well as to hold the traction member and weight carriers. It consisted of the frame, axles, wheels, bushes, pins and braces. The frame which was made of angle iron and flate iron was 2.2 meters long, 1.75 meters wide and 1.45 meters high. It weighed 400 kgs.

To run the suspension unit on the track, four cast iron wheels with diameter 28.75 cm were fitted to the square mild steel axles, welded to the frame.

Power Transmission Unit

The power transmission unit consists of a 3 hp, 1,440 rpm motor as prime mover which was coupled to a gear box by means of spur gears having speed reduction of 25:1 which was further reduced by the gear box by 7:1 (in first gear) at the sprocket fitted at the other end of the box. This was mounted on the suspension unit.

The power from the gear box was transmitted to the sprocket keyed on an intermediate shaft of diameter 3.8 cm and length 80 cm which was fitted in the lower part of the frame just below the gear box by means of two ball bearings. The power was transmitted from the gear box to the shaft by means of sprocket and ASA diamond roller chain of 1.92 cm pitch with a speed reduction of 2.17:1. Further power was transmitted to the final drive shaft of diameter 4.5 cm and length 180 cm by means of two sprockets and chains fitted at equidistance from the centre considering the equidistribution of forces on the shaft

Fig. 1a Traction Testing Unit (Plan)

Fig. 1b Traction Testing Unit (Elevation)

Fig. 1c Traction Testing Unit (Side View)

and bearings. The speed reduction was 1.34:1 hence, the total reduction was 30 rpm on the final drive shaft (lowest gear) or a speed of about 2.42 km/hr for a 75 cm diameter wheel.

The tire, was mounted on this shaft, which was, in turn, attached to the suspension unit by means of sleeves and two pipes and free to move upward and downward. The weight was transferred directly to the tires.

Weight Carriers

Two weight carriers were suspended on the shaft on both sides of the tire.

Track

Two 17-meter long I section pieces were fixed 2.17 meters apart and one meter high from the ground level to run the suspension unit during operation.

Soil Trough

The soil trough was 16 meters long and 1.37 meters wide and was installed between the tracks. Concrete slabs were placed in the centre of the trough to run the tire on concrete surface. These slabs can be removed, if the readings are to be taken on natural soil.

Loading Device

This device consists of a circular drum of 30 cm diameter, fitted with a prony barake. The cotton cable was wound on the drum with one end tightened to the suspension unit. A spring dynamometer placed in between measured the weight of the load.

Procedure

The test were conducted as follows:

1. A distance of 12 meters on concrete slabs from the starting point of the tire was marked.
2. The starting point of the wheel for recording the RPM was marked by an arrow.
3. A cable was wound on the drum of loading device with one end tightened to the suspension unit through a spring dynamometer.
4. The brake was tightened to drive the desired pull.
5. A voltmeter and an ammeter were connected to the line to measure the voltage and current of the load.
6. The switch was put on and as soon as the unit moved to the marked distance, was put off. The RPM of the wheel was counted for a 12-meter run and this distance was recorded by a stop watch. The pull was recorded by a spring dynamometer. The current and voltage were recorded from the ammeter and voltmeter.
7. Variable weights were placed on the weight carriers and the readings were recorded.

Result and Conclusion

To assess the accuracy of design and performance of the unit, tests were conducted with the tire of Beaver Tractor of the following design.

Tire size: 6-12, 2 ply (Firestone)

Table 1. Traction Performance of Beaver Tractor Tire Without Wheel Ballast*

Pull (kg)	Amperes	Time (see)	Drive-wheel RPM	Percentage Slip	Linear Speed	Drawbar HP
0	0.5	15.6	6.50	0	2.77	0
20	0.5	15.7	6.60	1.54	2.75	0.202
30	0.51	15.9	6.75	3.85	2.733	0.303
40	0.54	16.0	6.00	4.62	2.70	0.400
50	0.60	16.5	7.00	7.700	2.62	0.485
60	0.75	16.8	7.25	11.55	2.57	0.560
70	0.85	17.3	7.87	20.00	2.496	0.650

* Voltage used was 230.

Table 2. Traction Performance of Beaver Tractor Tire With 20 kg Wheel Ballast*

Pull (kg)	Amperes	Time (see)	Drive-wheel RPM	Percentage Slip	Linear Speed	Drawbar HP
0	0.50	15.5	6.50	0	2.782	0
20	0.50	15.6	6.55	0.77	2.77	0.204
30	0.52	15.7	6.60	1.55	2.75	0.304
40	0.62	15.9	6.75	3.85	2.72	0.408
50	0.65	16.2	6.875	5.78	2.666	0.494
60	0.85	16.6	7.20	10.70	2.602	0.578
70	1.00	17.1	7.625	17.32	2.527	0.655

* Voltage used was 230.

Table 3. Traction Performance of Beaver Tractor Tire With 40 kg Wheel Ballast*

Pull (kg)	Amperes	Time (see)	Drive-wheel RPM	Percentage Slip	Linear Speed	Drawbar HP
0	0.5	15.3	6.48	0	2.824	0
20	0.5	15.4	6.50	0.3	2.804	0.204
30	0.54	15.4	6.55	1.0	2.782	0.309
40	0.60	15.7	6.625	2.24	2.75	0.412
50	0.75	16.0	6.75	4.17	2.70	0.504
60	1.00	16.4	7.00	8.05	2.634	0.584
70	1.20	16.8	7.375	13.60	2.572	0.664

* Voltage used was 230.

Fig. 2 Relationship between Drawbar Pull and Slip

Outer diameter: 55 cm
Width of tire: 16 cm
Inflation pressure: 12 kg/cm^2
Surface of test area: Concrete

The test were conducted with a) no ballast and b) two different ballast conditions, viz. 20 kg and 40 kg at different pulls varying from 0 to 70 kg. The axle and weight carrier assembly resulted in a constant weight of 60 kg on the tire. Each test was repeated three times. The average values of the observation are shown in **Tables 1,2** and 3.

Fig. 3 Relationship Between Drawbar Pull and Linear Speed

Fig. 4 Relationship Between Drawbar Pull and Drawbar Horse Power

Relation Between Drawbar Pull and Slippage

The effect of drawbar pull on slippage is shown in **Fig. 2**. The curves indicate that an increase in drawbar pull increases slippage with a gradual rise of up to 40 kg pull. Thereafter the slip increased at a faster rate, resulting in a curvilinear relationship. The wheel weights caused a decreased slippage for a given pull.

Relationship Between Drawbar Pull and Linear Speed

The relationship between drawbar pull and the linear speed is shown in **Fig. 3**. The linear speed decreased as the drawbar pull increased for all cases because the increased drawbar pull offered more resistance, resulting in higher slippage and, hence reduction in travel speed.

Relationship Between Drawbar Pull and Drawbar HP

The relationship between the drawbar pull and the drawbar HP, with and without ballast is shown in **Fig. 4**. On concrete surface the drawbar HP is directly proportional to the drawbar pull. The trend of curves shows that the drawbar HP increases with an increase in drawbar pull.

Conclusion

The results confirm the general existing trends between the given variables and thereby prove the accuracy of design of the test unit. The unit is suitable for testing different sizes of tires varying up to 100 cm diameter.

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Design and Construction of a Manually Operated Castorbean-Cum-Sunflower Seed Dehuller

by
A. A. Mainul Hussain
Professor & Head
Department of Farm Power & Machinery,
Bangladesh Agricultural University
Mymensingh, Bangladesh

Md. Abdus Sabur
Assistant Engineer
Bangladesh Agricultural Development Corporation

Md. Matiur Rahman

Introduction

Hulled castorbean contains 35 to 55 percent oil which averages about 50 percent in well-developed seeds. Recent processes of dehydrating castor oil gives drying properties to the oil rendering usable for paints and varnishes. The world production of castorbean is about 60,000 tons (Martin et al. 1970). The leading countries in castorbean production are Brazil and India, but it is also grown in Mexico, Italy, Argentina and Indonesia as well so other countries of Africa, Asia and South America. In some parts of Bangladesh sunflower is grown as field crop for the purpose of oil production.

Attempts have been to grow castorbean in Bangladesh with limited success due to the non-availability of modern crushing facilities, removal of seed coat and solvent for oil extraction from this crop.

In Bangladesh about 1,040 acres of land produce, on the average, about 213 tons of castorbean a year (Alim, 1974). Sunflower seed production nearly equals that of castorbean. Oil from these seeds are extracted by some growers using small extractors. They still practice age-old method of extraction which result in substantial loss of oil from the seeds. Studies have revealed that the quality can be improved and quantity can be increased by adapting modern methods of extraction.

In processing castorbean and sunflower seed the dehuller plays an important role. The purpose of the dehuller is to remove the hulls without appreciable damage to the kernel. It is important that this operation be done as completely and as efficiently as possible. Cracked seeds lose oil and gradually become rancid. The trash, hulls and cracked beans reduce the quality of oil produced. The presence of foreign materials reduce the quality and quantity of oil and import an objectionable dark colour to the oil.

Attempts have been made in the past to develop castorbean and sunflower seed dehuller but were complicated and power operated. These dehullers are not suitable for small scale operation in Bangladesh.

The Seed Dehuller

The design and construction of the dehuller uses entirely locally available materials and is operated manually. The complete unit consist essentially of a hopper, a rotary drum feeder, and two horizontal rubber faced disks driven by human power. The clearance between the hulling disks can be adjusted independently making it possible to hull either castorbean and sunflower. One of two hulling disks is stationary and the other one rotating. The rotating disk is attached to the end of a vertical shaft. Power is transmitted to the rotating disk by two sets of chain and sprockets. The machine has an effective hulling area of about 56 square inch. The thickness of the rubber face on hulling disk is about 1/4 inch and is glued to the wooden disks. The rubber facing of the rotary disk is provided with 3/4 inch taper at the central opening. The taper is necessary for guiding the beans between the disks and increasing the capacity of the machine. Carefull consideration is given while selecting the taper since too much taper would overload the disk and increase the proportion of cracked kernels.

The fixed disk is attached to the

Plate 1 Castorbean-cum-sunflower seed dehuller

frame as shown in Plate 1. The inner face of the disk is covered with 1/4 inch thick rubber sheet. The fixed disk is attached to the top of the huller housing by four bolts. The spacing between the hulling disks can be adjusted by moving the rotary disk up and down along with the vertical shaft by the hand wheel.

Performance Test

The dehuller was tested at various speeds. Sunflower seed with moisture content of 16 percent and castorbean with moisture content of 20 percent were used for the test. The seeds contained about 20 percent to 35 percent immature ones which affected the hulling capacity considerably. The speed of the rotating disk was varied from 75 rpm to about 400 rpm. The result of this test indicates that as the speed increases the percentage of unhulled and cracked kernel also increases. The optimum speed was 120–150 rpm. At this speed the hulling capacity was 1 lb/min. The hulling quality at this speed was approximately 60 percent for castorbean and 70 percent for sunflower seed.

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Agricultural Engineering at Michigan State University

The Agricultural Engineering department at Michigan State University has just prepared updated summaries of teaching, extension and international programs. If you should be interested in copies of one or more of these three summaries, please write to the Department of Agricultural Engineering, Michigan State University, East Lansing, Michigan, 48824, U.S.A.

This department has graduated 171 M.S. and Ph.D. students from other countries while at the same time graduating 281 MS and Ph.D. American students. The International Summary also provides information on the various types of graduate degree programs available as well as some of the associated research projects. A brief description is also provided on each of the various collaborative and linkage programs with institutions in other countries in which the MSU Agricultural Engineering department has been involved. These include for example, programs in Indonesia, Japan and Brazil.

The department also has various affiliations with international agencies such as; the UNDP Food and Agricultural Organization and the United Nations Industrial Development Organization, the World Bank, the network of research institutes of IRRI, CIAT, IITA and ICRSAT and the Ford and Rockefeller Foundations.

The Michigan State University Agricultural Engineering department hosted the IX CIGR International Congress at East Lansing, Michigan, July 8–13, 1979. This was the first of the nine (once every five years) CIGR Congresses ever held outside of continental Europe. The American Society of Agricultural Engineers (ASAE) was a co-sponsor with MSU of the IXth CIGR Congress at East Lansing, Michigan. ASAE joined CIGR, which is a federation of national societies, in 1959. ASAE in contrast is a society of some 8,000 individuals. About ten percent of this membership consists of individuals residing in countries outside of North America.

Five MSU doctoral graduate students have carried out research in the area of post rice production technology and losses in tropical countries. Each of them has carried out field research for up to one year in either Indonesia, Sri Lanka or the Philippines. Systems modeling has been used as the analytical approach and simulation models developed for studying the feasibility of alternative methods of technology.

Only one published report is available at this time. It is the ASAE paper No.79. 5060 entitled Post Rice Production in-Field Losses in Sri Lanka, by Sarath Ilangantileke, Merle Esmay and Allan Phillips. A copy may be obtained by writing to the AE department at the address indicated above. ■■

Fendt Farmer 200S Tractor

A Farmer 200S tractor relieves the driver of fatigue while at work. Wide, low-slung stepping boards give easy access. The body-moulded, hydraulically suspended seat is adjustable for weight and leg length. All operating levers are within easy reach. The instrument panel, of modern styling, groups within ready view tachograph, speedometer, fuel gauge and all pilot lamps monitoring engine and lighting system. With the conveniently sited shift lever for the full synchromesh transmission, gear engagement is fast, smooth and simple. The quietly running 3-cylinder engine, throttled down to 2,000 r.p.m., keeps noise levels low. The cab with safety canopy, available as optional extra, rounds off the equipment designed for maximum driver comfort.

Power source of the hydraulics is a tough gear pump of simple design, mounted on the engine for easy accessibility. Service pressure is 175 bar/2,537 psi, max. delivery 34 l/min. The rear hydraulics operate on the principle of depth and traction control. A steplessly variable combined depth/traction control permits accurate ploughing in variable soil as well as shallow soil turning. Control pulses are transmitted to the hydraulic system via top link and hairpin sensor spring. Lifting power at the drawbar is 18.1 kN/1,840 kg. In addition to the main hydraulic control valve, two single or dual-acting control valves (max. 4 valves) with associated taps can be fitted.

Optionally, Farmer 200 S tractors in the 29 kW/40 HP version can be supplied in a 4-wheel drive version which gives most efficient power transmission in very heavy duty. The powerful front-wheel drive ensures accurate tracking without repeated counter-steering. A 4-wheel drive transmits maximum power to the front loader, makes work along the slope safer, as the engine brakes tractor and trailer securely via all four wheels. Front and rear axles are set as standard to 1,360 mm track width. The 4-wheel drive is engaged by heavy dog clutch. A slipping clutch, fitted as standard, provides overload safety. The 4-wheel-drive Farmer 200 S is exceptionally easy to manoeuvre, having a very tight turning circle radius of 8.2 m for its size.

(X. Fendt & Co.: Postfach 140, 8952 Marktoberdorf, West Germany)

Fendt 255 Kommunal-GT Tractor

With the Fendt-Kommunal tractor and its versatile attachment system all the operations which fall within the compass of municipal work throughout the year, can be carried out quickly and efficiently. This encompasses work ranging from upkeep and mowing to construction and repair work (services and drainage systems), from sweeping and cleaning operations to hard work during the winter.

The excellent stability of the tractor – especially important when mowing embankments, for example – is obtained by the below-floor position of the engine. The central swivel joint ensures that even on sloping ground and with considerable distortion of the tractor, it is always in contact with the ground at four points.

With the large steering lock combined with hydraulic steering a track radius of only 4.2 m is obtained. With the steering brake the vehicle can be turned on the spot.

75% of the weight of the vehicle is supported by the large drive wheels. Combined with the large rear wheel tyres the Kommunal-tractor has the tractive force of a 4-wheel drive tractor. When driving down an incline the position of the centre of gravity is only displaced very little ensuring the full braking power.

There are five working spaces available for different combinations of implements. It only needs one man to fit or remove any of the implements in the shortest time.

The hydraulic system consists of the power lift at the rear (32,000 N load), the between-axles hydraulics, the front power lift and the hydraulic connections.

Power take-offs (540 and 1,000 r.p.m.) are situated at the rear, between the axles and the front. They can be connected or disconnected while on load and during driving.

Three spaces for implements are situated in the direction of motion. The driver works on the "look ahead" principle.

The tractor can drive through thick and thin, even in open country (e.g. for land cultivation) due to its large ground clearance (480 mm).

[Specifications]
Dimensions: 4,637 x 1,850 x 2,564 mm (L x W x H), Weight: 3,275 kg, Engine: Air-cooled 3-cylinder 37 kW/50 hp/2,300 r.p.m., Speed: Forward 20/reverse 6.

(X. Fendt & Co.; Postfach 140, 8,952 Marktoberdorf, West Germany)

NEW PRODUCTS

Ford 4100 Tractor

The 4100 engine produces 52 hp (BS) at 2,200 rev/min, and maximum torque is 136 lb ft at 1,440 rev/min; while the 4,600 unit develops 62 hp (BS) at 2,200 rev/min, and 162 lb ft torque at 1,340 rev/min.

The 4100 is powered by the world-proven Ford 3 cylinder direct-injection diesel engine. With strong, rigid blocks, wide bores, large valves, and 4 bearing crankshaft turning on heavy duty bearings. The inherent balance of the 3 cylinder design means smooth running and low component stress.

The fuel injection, induction and exhaust systems have all been redesigned for quieter, cleaner combustion with low exhaust emissions and optimum fuel economy. A 46 amp high capacity alternator is now standard. And there's new dual element dry air cleaner, with an air flow restriction indicator light in the cab.

Compact and highly manoeuvrable, the 4,100 offers a "big tractor" specification that includes very powerful hydraulics, fully independent PTO, inboard wet disc brakes, and super luxury cab. It's the big-performance small tractor many farmers have been waiting for.

(Ford Motor Co., Ltd.: Basildon, Essex, England)

IH 3588 Articulated Tractor

The two + two wheeled drive concept combines the strength and traction of four-wheel drive with the mobility of two-wheel drive.

It enables farmers to get into fields earlier and stay longer, despite bad weather conditions.

Described by IH as, "A major breakthrough" in row-crop tractor design, the new 3588 is powered by an International six cylinder turbo-charged diesel engine of 180 h.p.

Exclusive design features covered by 15 world-wide patents have resulted in this articulated tractor embodying high standards of stability, weight distribution and efficiency. It has 16 forward speeds, adequate to cope with every type of farming operation.

For the driver, one of the plus features of the 3588 is the excellent manoeuvrability of the forward articulated unit. The driver, in the quiet and comfortable control centre on the rear section, is unaffected when steering corrections are needed, overcoming "side thrust" criticism that can be made of currently available central-pivot type tractors.

The full articulation allied to the hydrostatic power-steering enables the operator to handle the tractor and its mounted or trailing implements with full control at all times. Turning radius is only 16'3".

(International Harvester Co. of Great Britain Ltd.: P.O.Box 25, 259 City Road, London EC1P 1AD, England)

Vagmacor Power Tiller

This power tiller is designed for lowland rice field and powered by a 8 hp Briggs & Stratton gasoline engine. Features of the tiller are

as follows:

Versatile: Can be used for upland and lowland field preparation, for weed control in sugarcane fields or other row crops, for furrowing and leveling.

Two-speed drive: Low speed for plowing, furrowing and transport. High speed for puddling, rotavating and leveling.

Floatable: With floatable body attachment for operation in lowland rice fields submerged in water. Does not bog down even in deep areas.

High performance: The unique design of the machine and its various attachments make it efficient for either lowland or upland application.

Easy to Operate: The floatable body used during puddling and leveling ensures easy maneuverability of the machine even in deep area. Plowing is very light on the operator.

Minimum maintenance: Simple and heavy-duty construction ensures minimum maintenance. Parts are all locally available.

[Specifications]

Weight (without engine): 85 kg (including plow), Cage wheel operating speed: 60 rpm for plowing and travelling. 120 rpm for puddling, harrowing and leveling, Standard accessories: Moldboard plow with depth control wheel. Floatable body attachment 40 kg counterweight, Optional accessories: Rotavator and "duck foot" pivot attachment harrow.

(Victorias Agro-Machinery Corp.: 5th Floor VMC Building, 165 Legaspi St., Legaspi Village, Makati Metro Manila, Philippines)

Micron Sprayer-ULVA16

Pesticide application by means of rotary atomization is now a well-established technique in many countries of the world as the result of pioneering efforts in this field by Micron Sprayers Ltd.

This technique, both simple and very sophisticated, has been evolved through many years of experiment and design, constantly linked with practical experience in the field.

Micron Sprayer's philosophy is quite simple . . . "to produce droplets of a correct size according to the target it is intended to hit, containing a chemical dose appropriate to that target."

This concept of spraying has taken pesticide application a big step towards the desired aim of efficient, economical use of expensive raw materials.

The original machine, which has revolutionized pesticide application in the developing countries. Its atomizer (Micromax), turning at 7-8,000 rev/min, produces 75-micron droplets, which are ideal for controlled drift spraying. Can take up to 16 hp, 2 (D cells) batteries, giving maximum economy of ballery life.

The atomizer has two speeds of rotation and interchangeable nozzles, making it capable of producing 250-micron droplets for herbicide application and 75-micron droplets for fungicide and insecticide treatments.

(Micron Sprayers Ltd.: Three Mills, Bromyard, Herefordshire HR7 4HU, U.K.)

Bonser LS55SL Lift Truck

Increased capacity and greater stability in high lift situations are features of the new LS55SL agricultural rough terrain lift truck (Photo.), recently introduced by Bonser Engineering Limited, and shown at this year's Smithfield Show for the first time.

Other features of the truck, which replaces the old LS55, include restyled design profile, improved operator visibility and movement of fuel and hydraulic tanks away from the engine to give better accessibility for servicing.

(Bonser Engineering Ltd.: Giltbrook, Nottingham, England)

McConnel Power Arm 44C

The Power Arm 44 fits your tractor by a unique, Snap-on-Hitch – without a subframe – so you can put it on and take it off again in minutes. It will not interfere with mounting points so you can still keep your front end loader on the tractor. And if you have a cab, you can use the Power Arm in comfort from inside it, so bad weather doesn't hold up the job. But before you read more about the machine, have a look at the jobs it can do for you.

From February 1980 the Power Arm 44 becomes the Power Arm 44C. This model change distinguishes new specification and options as follows:

(1) Kontak hydraulic control unit – Simple to service, parts available worldwide.

(2) Remoe cable controls – Easy to fit in 'Q' cabs, simple and safe.

(3) Independent hydraulics – Standard with all flails, option for some tractors to dig and load.

(4) New bucket range – 10% more power at bucket lip better ejector plate design.

(F. W. McConnel Ltd.: Temeside Works, Ludlow, Salop, SY8 1JL, England) ■■

BOOK REVIEW

Conceptual and Policy Framework for Appropriate Industrial Technology

– Monographs on appropriate industrial technology No.1 –

(Austria)

To focus attention on issues involved in choosing and applying appropriate technology, UNIDO organized the International Forum on Appropriate Industrial Technology. The Forum was held in two parts: a technical/official-level meeting from 20 to 24 November 1978 at New Delhi and a ministerial-level meeting from 28 to 30 November 1978 at Anand, India.

There is a monograph for each of the thirteen Working Groups into which the meeting was divided: one on the conceptual and policy framework for appropriate industrial technology and twelve on the following industrial sectors:

- Low-cost transport for rural areas
- Paper products and small pulp mills
- Agricultural machinery and implements
- Energy for rural requirements
- Textiles
- Food storage and processing
- Sugar
- Oils and fats
- Drugs and pharmaceuticals
- Light industries and rural workshops
- Construction and building materials
- Basic industries

The monograph also includes the basic part of the report of the ministerial-level meeting and some papers which were prepared for the Second Consultative Group on Appropriate Industrial Technology, which met at Vienna, 26-29 June 1978.

Size: 24cm x 16cm, 144pp, with paper cover.

Published by United Nations Industrial Development Organization (U.N.I.D.O.), P.O.Box 707, A-1011 Vienna, Austria

A I T Research Summary August 1977 – August 1978

(Thailand)

Research in the Division during the year covered the areas of farm machinery and mechanization, primary products processing, soil and water engineering, solar energy, system studies and aquaculture.

In farm machinery and mechanization the research areas include: development of paddy awn thresher and manual seeder for soybean; dynamics of tractor-implement combinations; slip and draft studies; and field studies of agricultural mechanization.

Research activities in the primary processing area include: drying simulation studies on paddy and cassava chips; mechanical and thermal properties of grains and cassava; breakage strength determination of grains; and the evaluation of milling quality of paddy in relation to its mechanical properties.

Solar energy research includes work on solar powered refrigeration, development of a rice dryer for use on farms during the wet season harvest and performance studies on inexpensive solar air heaters.

In the area of application of system techniques, studies conducted included simulations of a sugarcane production system in Pakistan and a rice production system in Philippines.

Containes particulars on 32 research projects completed or in progress since August 1977.

This pamphlet measures 26cm x 18.5cm and has 21 pages.

Published by Division of Agricultural and Food Engineering, Asian Institute of Technology, P.O.Box 2754, Bangkok, Thailand.

Rice Postproduction Technology in the Tropics

(U.S.A)

This book discusses all of the critical postproduction operations for rice in the tropics. The principles and concepts of harvesting, threshing, handling, drying, storing and milling systems, along with their application, are presented in a semi-technical manner. The book is intended for undergraduate agricultural engineering students, although much of the material is understandable by non-engineers. The book should therefore fulfill a need as a reference for many people concerned about and involved in rice postproduction operations and systems.

The subject matter of the book is focused on tropical conditions which present unique problems of handling, storing, and processing as compared to temperature climatic areas. The book includes some sample analytical problems. Instructors are encouraged to supplement the example problems with local and regional conditions when ever possible.

The book is in English which may not be the most preferable language for some of you. The metric system of measurement has been used throughout so hopefully it is appropriate. The authors realize that this book being the first in its specific field, can be improved upon so intend to work towards updating, expanding and rewriting within a few years.

Written by Merle Esmay, Soemangat, Eriyatno and Allan Phillips.

The book was published through the Food Institute of the East-West Center by the University Press of Hawaii, Honolulu. It may be ordered from the University of Hawaii Press, Honolulu, Hawaii 96822 for $7.00.

Glimpses of Agricultural Mechanization in China

(U.S.A)

This one hundred page book with about one hundred pictures is a compilation of fifteen reports. Each of the members of the American Society of Agricultural Engineers delegation to China in August and September, 1979 contributed a report.

The individual reports reflect the various areas of expertise represented by the delegation members. About one-half of the group were from industry with the others being from Universities and a USDA research institute. Although the most prevalent focus was on farm power and machining the other fields of irrigation equipment, livestock production housing and mechanization, electrification, processing and storage were covered by the broad delegation expertise and investigated during the travels in China.

The ASAE delegation was invited to China and hosted while there by the Chinese Society of Agricultural Machinery (CSAM). The headquarters of CSAM is located in Beijing at the Chinese Academy of Agricultural Mechanization Science (CAAMS). The CSAM developed itinerary covered some 5,000 miles and took the delegation into many of the coastal provinces from the north to the south.

Seminars were presented to three hundred CSAM members in Beijing over a period of two days. Also it was arranged for the ASAE delegation to meet Vice Premier Wang, Ren Zhong who is responsible for all of the agriculturally related ministries. This includes the ministry of agricultural machinery. The China report includes the briefing presented to the delegation by Vice Premier Wang. Current and future plans and strategy for modernizing agriculture and increasing food production were revealed.

Merle L. Esmay and Roy E. Harrington are co-authors.

The book "Glimpses of Agricultural Mechanization in China" may be ordered for $10.00 from ASAE Headquarters, 2950 Niles Road, Box 410, St. Joseph, Michigan, 49085, U.S.A.

The Lost Harvest

(Italy)

The Food and Agriculture Organization's new Programme for Prevention of Food Losses responds to a long-standing need, which received some prominence at the Seventh Special Session of the United Nations General Assembly in 1975, when a call was issued to reduce post-harvest food losses in developing countries, by at least half, by 1985.

The campaign to cut food losses aims at giving practical help to the millions of small farmers upon whom most food supplies of the developing countries depend. It assists in carrying out projects demonstrating the most efficient ways of combating the many causes of food losses, using methods and technologies attuned to the special conditions and limited resources of those countries. The programme is catalytic in nature. Its pilot projects provide the groundwork for the subsequent broad frontal attacks on food losses that the national authorities will have to carry out on a continuing basis. They will need considerable support from international financing agencies and developed countries because in most cases their own resources will be inadequate.

This booklet is intended to increase understanding of the complexities of the food losses problem and of the tremendous opportunity this FAO Action Programme offers, to increase significantly the Third World's food supplies.

Size: 24cm x 17cm, pp.48 with paper cover.

Published by Food and Agriculture Organization of the United Nations: Via delle Terme di Caracalla, 00100 - Rome, Italy ■■

Co-operating Editors

B. K. Bala | M.A. Mazed | M. Gurung | T. T. Pedersen | G. B. Hanna | Satish Chandra | A. P. Sharma | A. M. Michael

Bilash Kanti Bala
Head, Dept. of Farm Power & Machinery, Bangladesh Agricultural University, Mymensingh, Bangladesh

M.A. Marzed
Head, Agricultural Engineering Division, Bangladesh Agricultural Research Institute, Sher-E-Bangla Nagar, Dacca-7, Bangladesh

Manbahadur Gurung
Horticulture Extention Officer, Ministry of Development Dept. of Agriculture, HA Bhutan P.O.HAA, Bhutan

T. Touggaard Pedersen
Professor, Agricultural Engineering at the Royal Velerinary–and Agricultural University, Copenhagen, Denmark

George B. Hanna
Chairman, Agricultural Engineering Dept., College of Agriculture, Cairo University, Giza, Cairo, Egypt.

Satish Chandra
Assistant Director of Agriculture, Koronivia Research Station, Ministry of Agriculture and Fisheries, P. O. Box 77, Narsori, Fiji

Amala Prasad Sharma
Agricultural Engineer, Koronivia Research Station, Ministry of Agriculture and Fisheries, P. O. Box. 77, Narsori, Fiji

A. M. Michael
Professor, Water Technology Center, Indian Agricultural Research Institute, New Delhi 110012, India

Siswadhi Soepardjo
Chairman, Agricultural Engineering Dept., Bogor Agricultural University, Japan Gunung Gede, Bogor, Indonesia

Giuseppe Pellizzi
Professor, Institute of Agricultural Machinery, University of Milano, Via G. Celoria 2–20133 Milano, Italy

Jun Sakai
Professor, Dept. of Agricultural Engineering, Faculty of Agriculture, Kyushu University 46-05, Hakozaki, Higashi-ku, Fukuoka 812, Japan

Bassan A. Snobar
Associate Professor, Faculty of Agriculture, University of Jordan, Amman, Jordan

Chang Joo Chung
Associate Professor, Dept. of Agricultural Engineering, College of Agriculture, Seoul National University, Suweon, Korea

Paris Andreou
Associate Professor and Chairman, Department of Agricultural Economics and Business, American University of Beirut, Beirut, Lebanon

Bala Krishna Shrestha
Assistant Agricultural Engineer, 4/141, Pulchowk Behind the Fire Brigade Latipur, Nepal

Adrian Moens
Head Professor, Dept. of Agricultural Engineering, Agricultural University, Dr. S.L. Mansholtlaan 12, Wageningen, Netherlands

Md. Shahansha-ud-Din Choudhury
Principal Research Fellow, Dept of Agricultural Engineering, Institute for Agricultural Research, Ahmadu Bello University, P.M.B. 1044, Zaria, Nigeria

Bherulal T. Devrajani
Principal Investigator, Sind Agricul-

Siswadhi Soepardjo | G. Pellizzi | Jun Sakai | Bassan A. Snobar | Chang Joo Chung | Paris Andreou | B. K. Shrestha | Adrian Moens

M. S. Choudhury | B. T. Devrajani | Mohammad Ilyas | A. A. Mughal | R. M. Lantin | Chul Choo Lee | R. P. Venturina | A. Kandiah

A. H. Abdoun M. A. Bedri Tien- song Peng Gajendra Singh John Kilgour W. J. Chancellor M. L. Esmay

ture University, Tandojam, Pakistan

Mohammad Ilyas
Agricultural Engineer, International Rice Research Institute (Pakistan), P. O. Box 1237, Islamabad, Pakistan (on leave to Philippines : 10&78, Agricultural Engineering Dept., IRRI, P. O. Box 933, Manila)

A. A. Mughal
Assistant Professor, Agricultural Engineering in the Faculty of Agricultural Engineering, Sind Agriculture College, Tandojam, Sind, Pakistan

Reynaldo M. Lantin
Dean, Institute of Agricultural Engineering and Technology, University of the Philippines at Los Baños, College, Laguna 3720, Philippines

Chul Choo Lee
Project Engineer, Projects Deaprtment, Asian Development Bank, P. O. Box 789, Manila, Philippines

Ricardo P. Venturina
Assistant Scientist for Agricultural Research, National Science Development Board, P. O. Box 3596, Rizal, Manila, Philippines

Arumugam Kandiah
Head, Dept. of Agricultural Engineering, Faculty of Agriculture, University of Sri Lanka, Paradeniya, Sri Lanka

Abdien Hassan Abdoun
Director General Administration for Engineering, Ministry of Agric., F & NR., Khartoum, Sudan

Mohamed A. Bedri
General Manager, Democratic Republic of the Sudan Ministry of Industry Project for Manufacture & Assembly of Trucks & Tractors, P. O. Box 1855 Khartoum, Sudan

Tien- Song Peng
Specialist, Plant Industry Div. Joint Commission on Rural Reconstruction 37, Nanhai Road, Taipei, Taiwan

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

John Kilgour
Lecturer in Engineering Drawing and Design, National College of Agricultural Engineering, Silsoe, Bedford. MK45 4DT, U.K.

William J. Chancellor
Professor, Agricultural Engineering, University of California, Davis, California 95616, U.S.A.

Merle L. Esmay
Professor, Agricultural Engineering, Michigan State University, East Lansing, Michigan 48823, U.S.A.

Chau Van Khe
Chairman, Agricultural Engineering Div. National Agricultural Center in Saigon, Ministry of Education Republic of Vietnam, 45 Chungde Saigon, Vietnam

New Co-operating Editor

Naresh Chandra Saxena

Date of Birth: 16, January, 1940
Place of Birth: Ajmer, India
Nationality: Indian
Address:
Faculty of Agricultural Engineering, Universiti Pertanian Malaysia, Serdang, Selangor, Malaysia.

Educational Qualifications:
(a) High School – 1955, First division, (Physics, Chemistry, Maths), Ajmer Board, India.
(b) Intermediate – 1957, First division (Physics, Chemistry, Maths), Ajmer Board, India.
(c) B.E. (Civil) – 1963, II division, Civil Engineering, Jodhpur University, India.
(d) M.S. – 1970, 3.00/4 GPA Structures Ohio State University, Columbus (Ohio), U.S.A.
(e) ph. D. – 1972, 3.1/4 GPA Engineering-Mechanics, Ohio State University, Columbus (Ohio), U.S.A.

Experience:
(a) Field 3 years 1963 to 1966 – Construction Engineer, Govt. of India. (Design & Construction of buildings, and Hill-Roads).
(b) Teaching Total – 12 years
1966 to 1968 – Assist. Prof. Udaipur University, India.
1968 to 1972 – Teaching Assistant Ohio State University, U.S.A
1972 to 1974 – Assist. Prof. Udaipur University, India.
1975 to 1977 – Mosul University, Iraq
1978 till to date – Universiti Pertanian Malaysia.

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