International specialized media for agricultural mechanization in Asian developing countries.

AMA

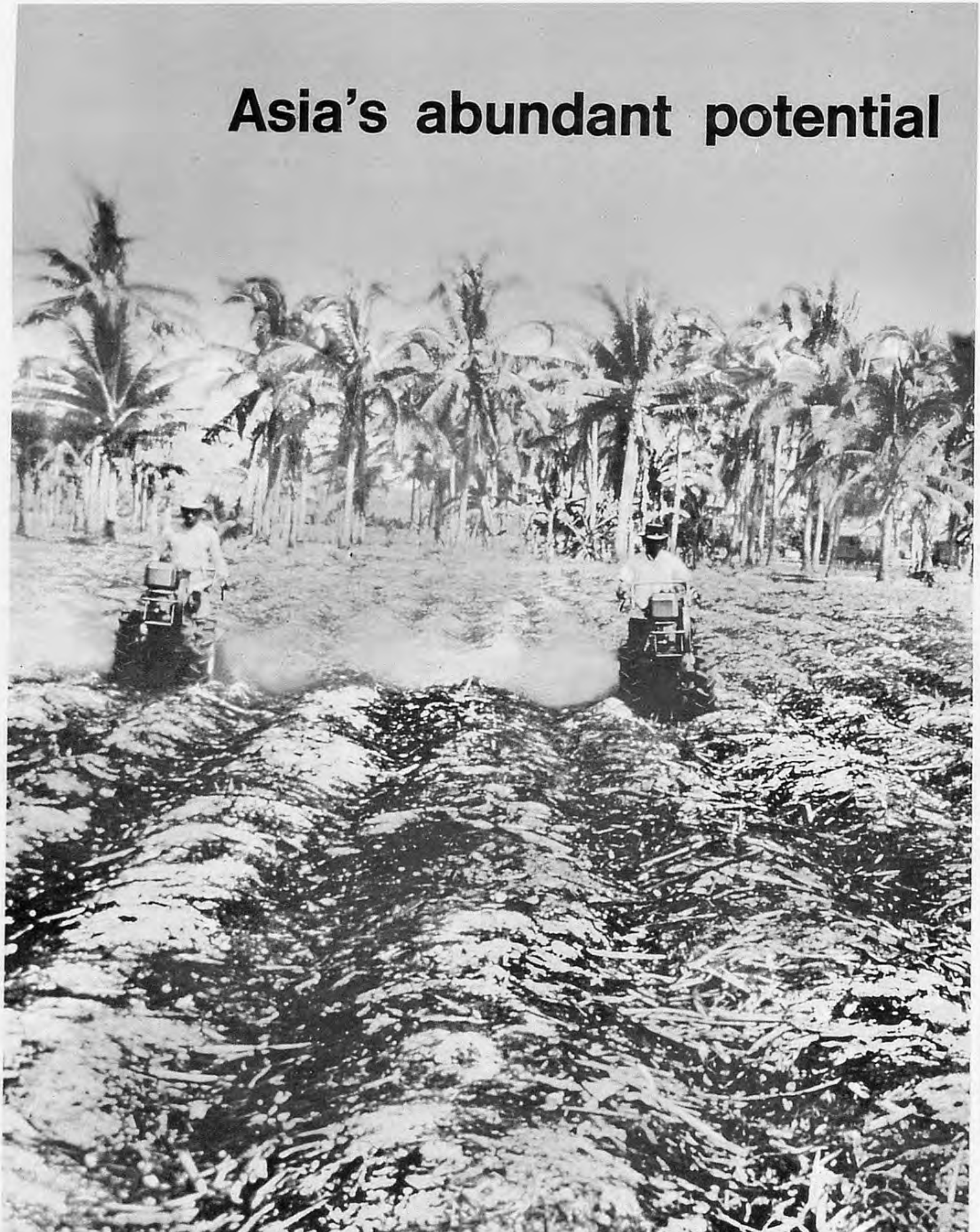
AGRICULTURAL MECHANIZATION IN ASIA

VOL. IV, NO. 2, AUTUMN 1973

Multiple-Cropping and Mechanization
Rice Drying and Storage

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

Asia's abundant potential

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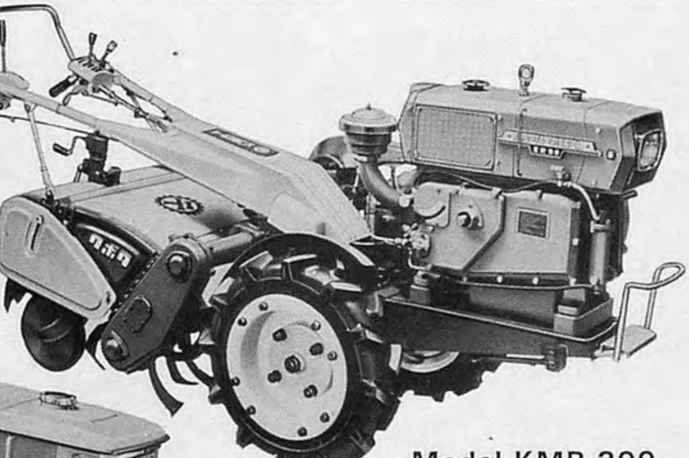
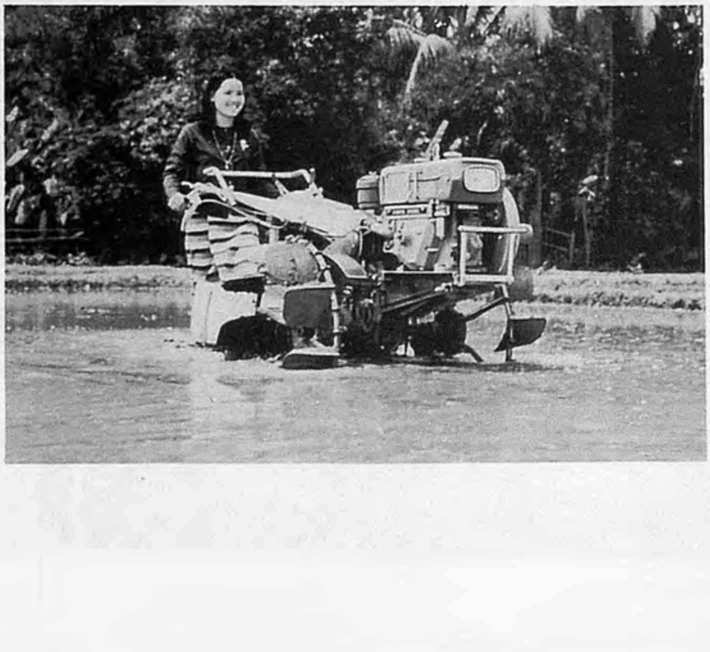
POWER TILLERS manufactured by Kubota, such as models KMB, K700, K500 and KF, are extremely versatile and efficient. They go easily into wet, muddy paddy fields for fast, complete work, making sharp pivot turns so that the entire area is worked, even in small, oddly shaped fields. Tilling, harrowing, weeding, etc., on dry land is just as effective. The wide variety of attachments available permit all types of jobs to be done, at any time of day or year.

MODEL	Engine model	Engine output	Speeds	Tiling width (Standard-max. with extension shaft)	Number of rotary blades (Standard)
K500	ER50-2	5-6.5HP/ 2,200rpm	Forward 6 Reverse 3	480–600mm	16 pcs.
K550	ER50-2	5-6.5HP/ 2,200rpm	Forward 6 Reverse 2	480–600mm	14 pcs.
K700	ER65-2	6.5-8HP/ 2,200rpm	Forward 6 Reverse 2	510–600mm	18 pcs.
KF	KND70	7-9HP/ 1,600rpm	Forward 4 Reverse 1	480–750mm	14 pcs.
	KNDR70L	7-9HP/ 1,600rpm			
KMB200	KND90	9-12HP/ 2,000rpm	Forward 6 Reverse 2	600mm	20 pcs.
	KNDR90	9-12HP/ 2,000rpm			



Model KMB-200

Model K-700



ENGINES

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Economical DIESEL ENGINES made by Kubota, in the ER, KND series, etc., provide power for all farm needs. Light in weight, but with great durability and power, they are used on power tillers and other equipment, and to operate all kinds of farm systems. Kubota's GASOLINE and KEROSENE engines are also extremely tough and serviceable.

MODEL		Output	rpm.	Net weight
HOPPER COOLING	KND 3	3~4HP	2,000	60 kg/132 Lbs
	KND 40	4~5HP	2,000	65 kg/143 Lbs
	KND 5B	5~6.5HP	2,200	75 kg/165 Lbs
	KND 70	7~9HP	1,600	112 kg/246 Lbs
	KND 90	9~12HP	2,000	135 kg/297 Lbs
	KNDR 70L	7~9HP	1,600	100 kg/219 Lbs
	KNDR 90	9~12HP	2,000	145 kg/318 Lbs
RADIATOR COOLING	ER 30	3~3.5HP	2,000	55 kg/121 Lbs
	ER 40	4~5HP	2,000	60 kg/132 Lbs
	ER 50	5~6.5HP	2,200	65 kg/143 Lbs
	ER 65	6.5~8HP	2,200	75 kg/165 Lbs
	ER 75	7.5~9HP	1,800	108 kg/238 Lbs
	ER 90	9~12HP	2,000	145 kg/319 Lbs
	ER 100	10~13HP	1,800	153 kg/337 Lbs
	ER 150N	15~18NP	1,800	247 kg/543 Lbs
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IRRIGATION SYSTEMS

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Irrigation systems are manufactured by Kubota in many different sizes, suitable for individual fields or entire agricultural areas. This company's PIPE, of ductile iron, asbestos-cement, or PVC, and PUMPS and VALVES are widely used in complete irrigation systems, to grow larger crops in areas where water is scarce.

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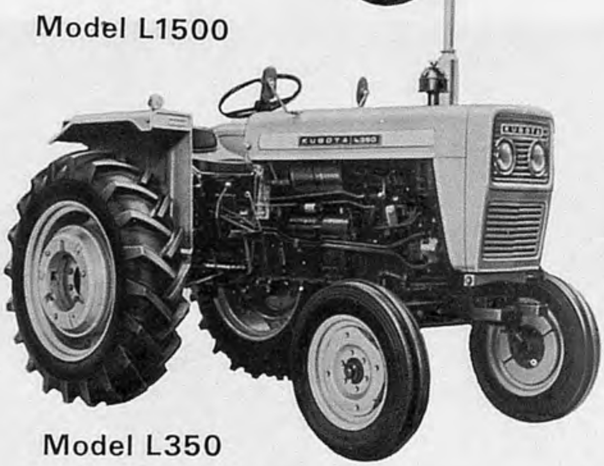
Model	Engine output	Ground clearance	PTO rpm	Weight
L1500	15 HP	330 mm	597/850/ 1,185/1,371	638 kg/1,400 lbs.
L2000	20 HP	350 mm	576/820/ 1,140/1,430	695 kg/1,529 lbs.
L260	26 HP	370 mm	541/696/ 984/1,266	1,000 kg/2,205 lbs.
L350	35 HP	484 mm	565/1,062	1,440 kg/3,170 lbs.

Model L1500

Model L2000



Model L350

Model L260

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KANEKO FDA (Floating Dryer & Aeration) System

KANEKO FDA System is very suitable for rough rice harvested at high moisture contents.

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4. with high head yealds

Good taste and unbroken rice by FDA has so market value that everyone who employs it makes many profits.

PRINCIPLES OF THE **FDA** SYSTEM

1. FDA System is accomplished by combining rationally two processes, namely, high moisture contents of rough rice is dried in large volume at high speed, and lower moisture contents of one is dried gradually at slow speed.
2. High moisture contents of rough rice is continuously pre-dried at high speed by Floating Dryer in which rough rice is dried by exprosure to a hot and strong air for short period, and foreign materials are remved.
3. FDA System is provided with a humidity control so that rough rice supplied into the aerated dryer in the evening is evenly dried as same as one supplied into the aerated dryer in the early morning.
4. FDA System is provided with a mechanism by which rough rice can be automatically dried to predetermined moisture contents.

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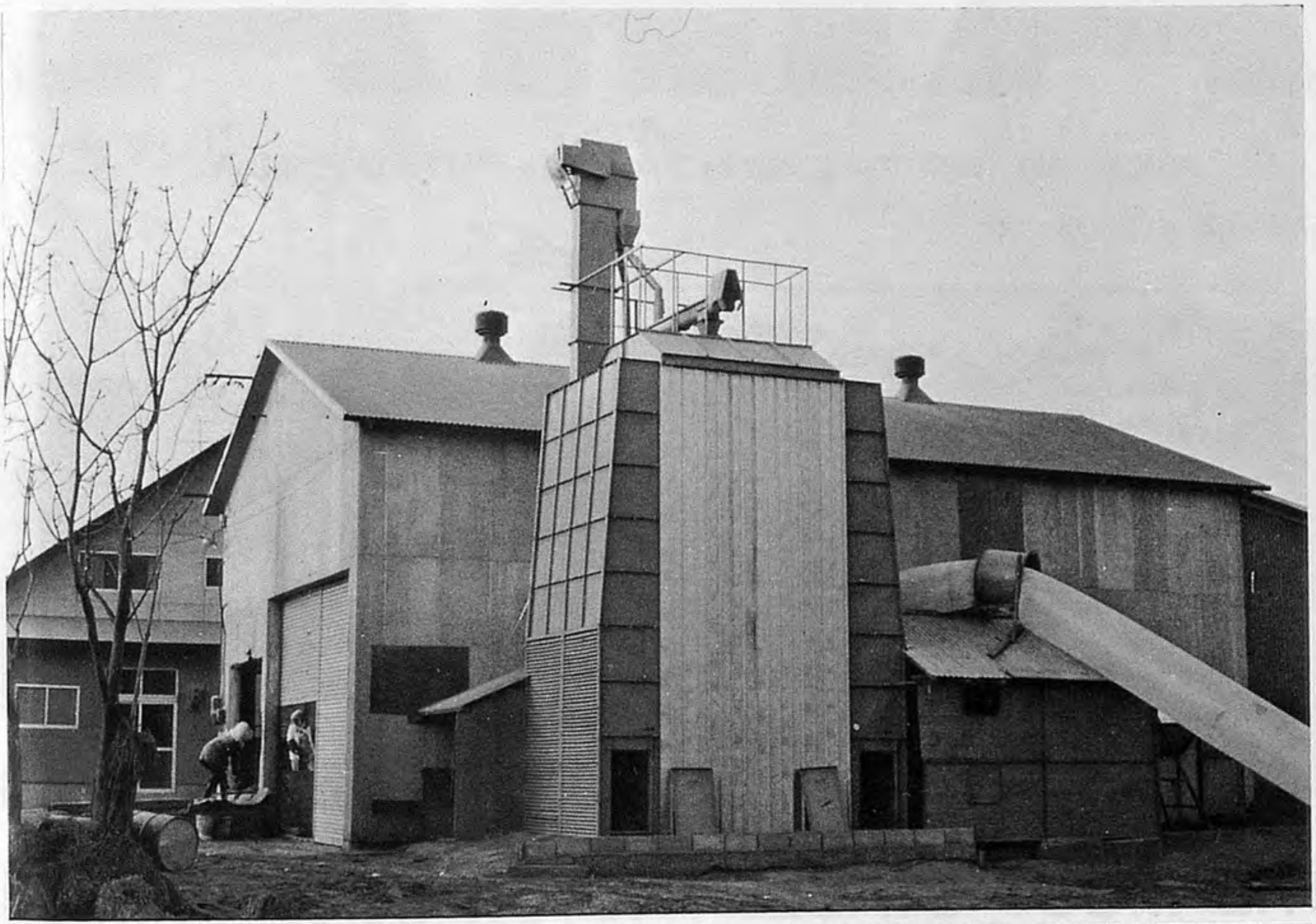

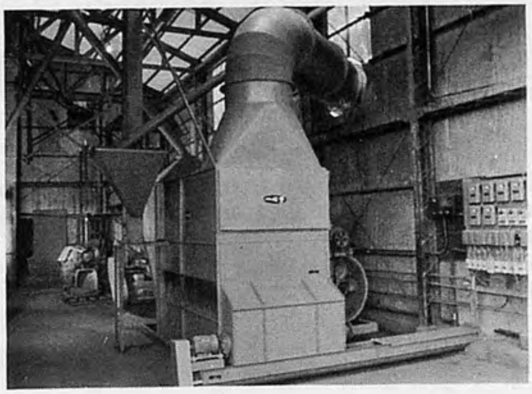

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YOSHISUKE KISHIDA

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Preface

This is the second issue titled with "Multiple Cropping and Mechanization".

After we published the last issue for the theme of "Multiple Cropping and Mechanization", we got the news about the severe food shortage problem in West African countries. More than half of cattles were killed or dead. This caused severe decrease of agricultural production power for next year.

Recently I met a person who had just come back from Africa and heard the dark prospect for harvesting of this season. This kind of story can be found not only in Africa but also another developing countries in Asia, which will be increased in the near future in many countries.

We always have the basic problem "How to balance between food and population in this limited surface of the earth". We need to take two ways at the same time, those are to control population and to develop intensive agriculture.

It is essencial for each farmer to select suitable combination of crops to maximize his total income and land productivity. Most of agricultural technology was developed to maximize the yield of single crop in many countries. But the needed technology from now is that for multiple cropping farming. We have to consider how to maximize the total production of a set of different crops. We have to develop different level of system for mechanization.

Agricultural engineers should consider mechanization system as a group of machinery. This cause very complicated problems for engineers. But this is so challengable problem which will be one of the most important method for the solution of the food-population problem.

Now, we also added another theme as "Rice Drying and Storage" which is very important to decrease the loss after harvesting in present developing countries.

We want to publish one of the future issue on this subject. We deeply appriciate every contributors and expect future contribution of article from every country. As to the theme of "Multiple Cropping and Mechanization", we will set a chapter in every future issue because this subject is so important and not yet fully studied.

Yoshisuke Kishida

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★News from Co-Operating Editors★

★ ★ ★

Possibilities of Multiple Cropping in the Rainfed Areas of India

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Dry land areas of India are characterized by scanty, ill distributed and uncertain rainfall occuring in a fitful manner. However, rainfall alone is the sole source of water for crop production in rainfed conditions. Cropping intensity in such situations, is generally low and traditional farming techniques do not appear to overcome this barrier. It is also essential to indicate here that multiple cropping involves cultivation of more than one crop in one calender year. Thus, the practice is wedded to a multiplicity of problems involving soil, water, crop, fertilizer and management relationship to make best use of the rain water. Nevertheless, the possibility of multiple cropping on a limited scale could not be ruled out. But, such an endeavour would involve an integrated approach.

This paper is an effort to project the ideas chiefly based on the research information available under Indian conditions. Though, no universal blue print can be advanced yet the reported research findings may be applicable under idential edaphic and environmental situations either as such or after their suitable trimming and tailoring to existing needs.

Essential Ingradients of Success in Rainfed Agriculture

Climate

A critical study of climatic conditions of the area constitutes basic ingradient of success in multiple cropping in rainfed countries/regions. Meteorological studies would involve investigations on rainfall characteristics, temperature and potential evapo-transpiration. These studies are to be conducted in various localities/regions to specify iso-climatic tracts.

Rainfall Characteristics

Besides quantum, the frequency, intensity and distribution of rainfall are extremely important for profitable crop production in dry land areas. The data on average annual rainfall and its coefficient of variability should be gathered and shown on the map of the area concerned as has been done in India by Koteswaram (1970) as shown in **Fig. 1.** Sreenivasan (1972) reported the period of water availability and rainfall in the different states of India. The data for some of the tracts are set out in **table 1.**

Periodicity of Drought

In fact, the weekly rainfall round the year should be studied over a period of decades to pinpoint the likely failure of rain alongwith its periodicity for different agro-climatic situations. Using the rainfall data, the dry land areas should be demarcated. Bali and Tamhane (1970) delineated the different intensity class-

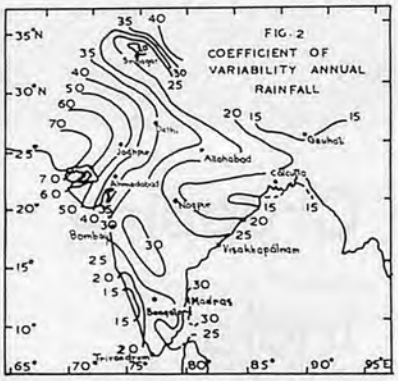


Fig. 1. Coefficient of variability of annual rainfall at various places of India.

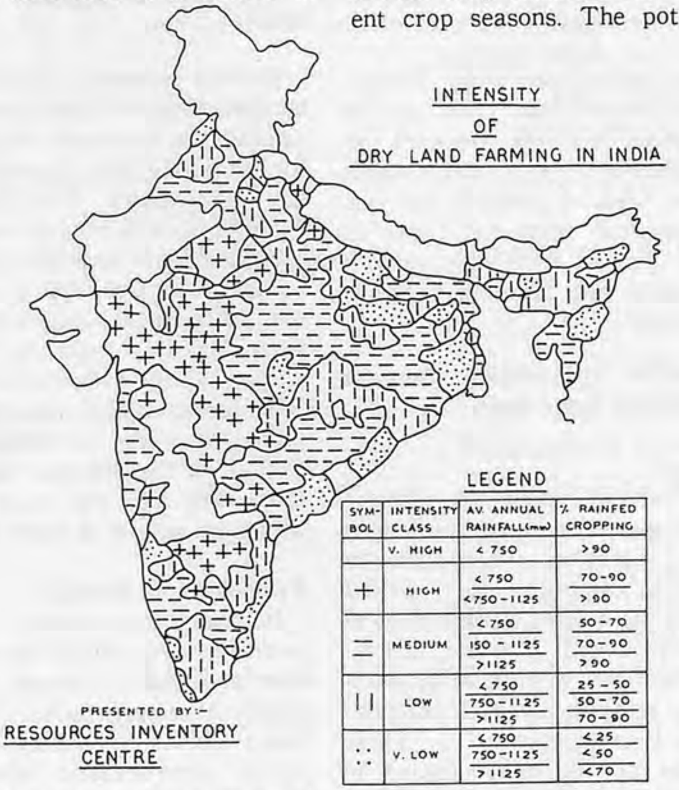
Source: Dr. P. Koteswaram (1970) Climatological studies for dry land condition in India. Paper presented at All India Seminar on Dry Land Farming, New Delhi, Jan., 1970.

Table 1: Rainfall and water availability for crop planning in various meteorological subdivisions of India.

Meteorological sub division	No. of stations	Average Annual		Duration of moist period		
		Rain-fall (cm)	Sur-plus (cm)	Without storage (days)	With storage (days)	Average annual deficit (cm)
Uttar Pradesh	9	108	46	138	214	66
Haryana (west)	3	71	11	122	157	91
Punjab	5	85	20	156	192	70
Rajasthan (west)	6	29	0	70	70	158
Rajasthan (east)	6	69	20	70	155	144
Saurashtra & Kutch	6	54	10	82	107	132
Marathwada	1	71	5	130	150	104
Vidarbha	7	115	50	134	186	73
Jelangana	7	98	29	141	210	77
Rayalasema	4	66	4	135	149	107
Interior Mysore (south)	6	81	12	173	202	58
Gujrat	5	90	38	122	185	92

Source: P.S. Sreenivasan (1972). Rainfall and evapotranspiration in relation to crops and crop planning. Indian Farmg. 22 (2): 38–42.

es in dry land areas of India as shown in **Fig. 2**. The periodicity of drought alongwith its intensity should also be determined for different regions so that cropping may be accordingly planned. Such information available under Indian conditons is presented in table. 2.



LEGEND

SYMBOL	INTENSITY CLASS	AV. ANNUAL RAINFALL(mm)	% RAINFED CROPPING
	V. HIGH	< 750	>90
+	HIGH	< 750 <750-1125	70-90 > 90
=	MEDIUM	< 750 150 - 1125 >1125	50-70 70-90 >90
‖	LOW	< 750 750-1125 >1125	25 - 50 50 - 70 70-90
⁘	V. LOW	< 750 750-1125 > 1125	< 25 < 50 <70

Fig. 2. Intensity classification of various dry land farming areas in India.

Source: Y.P, Bali and R.V, Tomhane (1970). Extent and intensity of dry land farming. Paper presented at All India Seminar on Dry Land Farming held at New Delhi, Jan., 1970.

Evapo-Transpiration

It is the common experience that temperatures of the predominantly dry farming regions are usually high. The variation on yearly basis is also large. Such conditions call for rigorous and critical crop selection for different crop seasons. The potential evapo-transpiration in such areas usually exceeds rainfall which necessitates effective conservation measures. Research information for individual regions is essential to knit appropriate crops in a multiple sequence to attain maximum water use efficiency and cropping intensity. Sreenivasan (1972) reported rainfall vis-a-vis potential evapotranspiration under varying agroclimatic conditions in India and some of the data have been presented in **table 3**.

These data are important since the water deficiency for a proposed cropping sequence can be extrapolated which will finally help in the selection of suitable crops to match the available soil water resources. Therefore, the authors open that information on potential evapo-transpiration and soil moisture situation under different agro-climatic conditions should be gathered in dry land regions intending to practise multiple cropping.

Soil

Moisture retentivity is primarily a function of texture and organic matter status of the soil. In dry land countries prevalance of high temperatures nearly rules out the build up of soil organic matter status. As such, soil texture assumes an added dimension in dry land regions. Rain water

Table 2: Periodicity of occurence of deficient rainfall in various meteorological sub divisions of India.

Meteorological sub-divisions	Recurrence period of highly deficient rainfall
West Bengal, Madhya Pradesh, Konkan, Coastal Andhra Pradesh, Madhya Maharashtra, Kerala, Bihar, Orissa.	Once in 5 years
South Interior Mysore, East Uttar Pradesh, Vidarbha	Once in 4 years
Gujrat, East Rajasthan, West Uttar Pradesh, Tamil Nadu, Kashmir, Rayalaseema, Jelangana	Once in 3 years
West Rajasthan	Once in 2.5 years.

Source: P. Koteswaram (1970). Climatological studies for dry land farming in India. All India Seminar on Dry Land Farming, held at New Delhi, Jan., 1970.

use and its storage efficiency will greatly depend upon the soil type. Further, the same quantity of rainfall in dry land conditions of southern India will have higher efficiency than in northern part of the country. In Kovilpatti district of Tamil Nadu pearl-millet gives some yield due to one rainfall alone. But, the same will not hold good in Rajasthan, parts of Haryana, Punjab and Gujrat. Therefore, it appears imperative to prepare soil maps along with range of available moisture and soil capacity to store/hold moisture. This will greatly help in water budgeting for successful crop production. This information is to be gathered for individual edaphic regions on national scale. In India, there is natural regionalization of crops in various soil types viz. pearl-millet in Rajasthan and Gujrat, Sorghum in Madhya Pradesh, Maharashtra, Andhra Pradesh and Mysore, Cotton in Gujarat and Maharashtra (in black cotton soils). These crops are mostly grown under rainfed conditions and can be arranged in appropriate rotations of varying intensities depending upon soil moisture situation.

Dry land soils are not only thursty but, hungry too. Hence, balanced fertilization using methods of known efficiency could be made use of. Placement of fertilizers at sowing time appears capable of greater utility in dry land conditions. Use of organic manures wherever possible could be largely helpful to produce good crops. In dry land countries iso-fertility regions should be demarcated and fertilizer recommendations should be formulated using soil test as well as crop correlation information. These points will be discussed at length elsewhere in this paper.

Selection of Crops

An ideal crop for dry land areas should possess physiological and morphological attributes associated with continuance of growth and avoidance of moisture stress conditons (Asana, 1970).* Keeeping in view the fore-said points a suitable crop for dry land regions should be photo-insensitive, early in maturity, capable of extracting moisture from soil at high tension and above all having high economic utility. Asana (1970) developed a model wheat plant type for dry land conditions. He specified the leaf-orientation, effective root zone, time of ear emergence and leaf characteristics etc. Similar plant types for the crops chosen for dry land areas should be worked out, and the specifications should be given to the plant breeders to breed the varieties accordingly.

Bali and Tamhane (1970) have indicated the existing cropping patterns showing major crops grown in the very high, high and medium intensity of dry land areas as indicated in **table 4.**

---

* R.D. Asana (1970). Improving plant material and cropping patterns for dry land areas. Paper presented at the All India Seminar on Dry land Farming held at New Delhi, Jan. 1970.

Table 3: Normal rainfall and potential evapotranspiration in various periods and on annual basis in different meteorological sub-divisions of India.

Meteorological sub-divisions	No. of stations	Rainfall/PE in cm for the period									
		Jan. to February		March to May		June to September		Oct. to December		Annual	
		R	PE	R	PE	R	PE	R	PE	R	PE
Uttar Pradesh (West)	9	5.5	12.4	4.0	49.0	89.5	59.0	5.3	22.7	104	143
Haryana	3	6.1	12.6	4.3	51.8	60.1	69.9	5.4	23.5	76	158
Punjab	5	5.9	10.0	4.7	46.9	49.1	65.5	4.4	19.7	65	142
Rajasthan (West)	6	1.1	15.4	2.1	59.6	26.1	80.6	1.3	38.2	31	184
Rajasthan (East)	6	1.4	14.4	2.3	53.4	63.3	61.6	4.1	25.0	71	155
Saurashtra and Kutch	6	0.3	22.7	0.5	61.2	54.9	62.5	3.9	37.6	60	184
Marathawada	1	1.4	21.5	3.3	63.5	65.3	58.1	9.0	37.1	79	175
Rayalaseema	4	1.2	25.9	6.8	57.6	38.8	60.5	19.1	32.7	66	177
Interior Mysore (South)	6	1.0	24.4	15.5	48.5	41.7	47.9	21.7	31.8	65	153

R = Rainfall : PE = Evapo-transpiration

Source : P.S. Sreenivasan (1972). Rainfall and evapo-transpiration in relation to crops and crop planning. Indial Farmg. 22 (2) : 38–42.

Singh (1972) experimented with rainy and winter season crops to indentify efficient and stable crops under rainfed conditions of Delhi. These crops were grown in two course rotations and the data have been presented in **table 5.**

An examination of these data would reveal that pearl-millet in rainy season while mustard in winter proved most efficient and stable crops over a period of two years. These results have further been corroborated by the observations made in Dry Land Cropping Cafetaria at the Indian Agricultural Research Institute (De, Turkhede and Ganga Saran, 1973). The important data on economics of crop production from 1970 to 1973 have been presented in **table 6.**

Crop Varieties

Having isolated and identified the efficient crops for a specific dry land situation, it becomes essential to choose right type of varieties thereof. Swaminathan (1969) reported different varieties of various crops which have been bred for rainfed areas of India. The list of these crops and varieties has been given in **table 7.**

Proposed Cropping Systems

The foregoing information on efficient crops and crop varieties will help in proposing various multiple cropping systems for rainfed conditions. Mann and Kanwar (1968) reviewed the proposed cropping patterns for different regions of India. Some of them, proposed for the different rainfed conditions have been quoted below.

Rajasthan (Arid region)

(a) Udaipur, Chittor and Banswara-maize/rainy season pulse-wheat, Hybrid pearl-millet-barley/gram.

(b) Alwar, Bharatpur and Sawai Madhopur-Rainy season pulse-wheat, Hybrid pearl-millet-gram, Groundnut-wheat.

(c) Jaiiselmer, Barmer and Jodhpur-Hybrid Sorghum-gram, Hybrid pearl-millet-fallow-rainy season pulse.

Punjab and Haryana

Table 4. Crops for dry land areas having varying intensity of dry farming.*

Intensity	Crops
Very high	Pearl millet, sorghum, groundnut, cotton, sesamum and some wheat, gram and barley.
High	Sorghum, wheat, cotton, grain pearl millet, groundnut, rice and some red gram and finger millet.
Medium	Rice, wheat, gram, maize, finger millet, sesamum rape seed and barley.

* Source: Y.P. Bali, and R.V. Ramhane. (1970). Extend and intensity of dry land farming. Paper presented at the All India Seminar on Dry Land Farming, held at New Delhi, Jan., 1970.

Table 5. Performance of various rainy and winter season crops under rainfed conditions at Delhi (India)* (grain q/ha).

Rainy season crops	1969	1970	Mean
Pearl-millet	29.25	22.40	25.82
Red gram	–	12.80	12.80
Sorghum	3.44	23.93	15.93
Green gram	4.66	6.91	5.79
Soybean	7.90	9.36	8.61
Maize	22.76	28.75	25.75
Winter season crops			
Wheat	5.48	4.24	4.85
Barley	13.64	11.49	12.08
Mustard	21.85	19.35	20.60
Bengal gram	10.38	8.00	9.19
Linseed	9.06	3.57	6.32

* Source: R.P. Singh (1972). Studies on the efficiency and economics of fertilizer use for major kharif and rabi crops grown under rainfed conditions. Ph. D. thesis, submitted to Faculty of Agriculture, Agra University, Agra.

Table 6: Economics of crop production under rainfed conditions at the Indian Agricultural Research Institute, New Delhi – 1970–72.

(Rainy season)

Crop	Variety	Grain (q/ha)			Net return (Rs/ha)			Average
		1970	1971	1972	1970	1971	1972	1970–72
Castor beans	Aruna	23.3	20.2	23.7	2256	2636	2865	2586
Red gram	AS–5	24.0	14.8	17.5	2246	1024	1602	1624
Pearl-millet (T)	HB–3	30.0	28.0	25.5	1406	937	1509	1284
Pearl-millet (S)	HB–3	22.0	21.5	21.5	798	517	1157	824
Sorghum (G.F.)	Local	398.0	277.0	336.0	1042	558	808	803
Sorghum (D.F.)	Local	150.0	89.2	116.0	552	62	286	300
Cowpea (G.F.)	EC 6342	204.0	277.5	212.3	219	572	256	329
Soybean	Clark–63	7.3	11.8	7.3	–51	178	98	75
Cluster bean	FS 277	10.5	10.0	8.3	–159	–289	–364	–237
Sorghum	Swarna	5.0	25.0	9.0	–359	1565	188	484

(T) = transplanted; (S) = Direct seeded
(G.F.) = Green fodder; (D.F.) = Dry fodder

(Winter season crop)

Crop	Variety	Grain (q/ha)			Net return (Rs/ha)			Average
		1970	1971	1972	1970	1971	1972	1970–72
Wheat	Kalyan sona	9.5	12.5	37.5	272	145	2036	736
Wheat	HD–4502	—	15.0	35.1	–	345	1830	1087
Barley	Ratna	19.5	25.0	31.2	283	936	1752	990
Rape seed mustard	BSH–1	20.5	13.5	18.0	2406	1698	1911	2005
Rape seed mustard	P.K.	–	–	24.0	–	–	2966	2966
Safflower	Nag–7	–	–	32.2	–	–	2708	2708

Source: Rajat De. B. B. Turkhede and Ganga Saran (1973). "Dry land cropping, cafeteria" Study in progress in the Division of Agronomy, Indian Agricultural Research Institute, New Delhi (India).

Panicum/pearl millet-wheat
pearl-millet-barley/wheat/gram
cotton-oil seed

Uttar Pradesh

Bundelkhand and Vindhya region-Hybrid sorghum-wheat.

Such cropping systems have been proposed for all states of India. Keeping in view the soil and rainfall characteristics, it is important to note that double cropping and even treble cropping has been proposed for the areas of low and medium rainfall as well as high temperatures. The success in these systems will primarily be attainable through application of modern agro-techniques. The authors are of the view that only efficient crops should be knitted in the multiple cropping systems for rainfed areas.

A mention has been made in the preceding paragraph regarding the package deal with respect to crop production. This has been briefly discussed and substantiated with the available research information under Indian conditions. The information may find practical application in regions and countries having identical edaphic and environmental conditions elsewhere.

Production Techniques

Table 7. Crops and their varieties suitable for rainfed conditions in India.*

Crop	Season	Variety
Wheat (Triticum aestivum)	Winter	Kalyan Sona, HD–1467, HI–6–23.
Wheat (Triticum durum)	,,	A 9–30–1
Barley	,,	RS 6, Ratna
Sorghum	Rainy and Winter	CSH–1 and M 35–1
Pearl-millet	Rainy	HB–3
Maize	,,	Ganga–5 and vikram
Castor	,,	Aruna
Red gram	,,	Pusa Ageti (early)
Cotton	,,	PRS 72

* Source: M.S. Swaminathan (1969). "Development and Introduction of a new agriculture strategy for unirrigated areas with low rainfall" back-ground paper for discussion held in the Planning Commission of India.

Traditional farming methods in rainfed conditions would not be able to sustain multiple cropping. Therefore, appropriate techniques should be developed to suit the soil and climatic conditions of the locality to augment rain water use efficiency in such areas.

Transplanting of pearl-millet on raised seed bed in the Dry Land Cropping Cafeteria at the Indian Agricultural Research Institute have postulated the possibilities of double cropping under dry land conditions. **Fig. 3a** depicts the methods of cropping both in rainy and winter seasons and **Fig. 3b** shows the soil moisture depletion pattern in ditches,

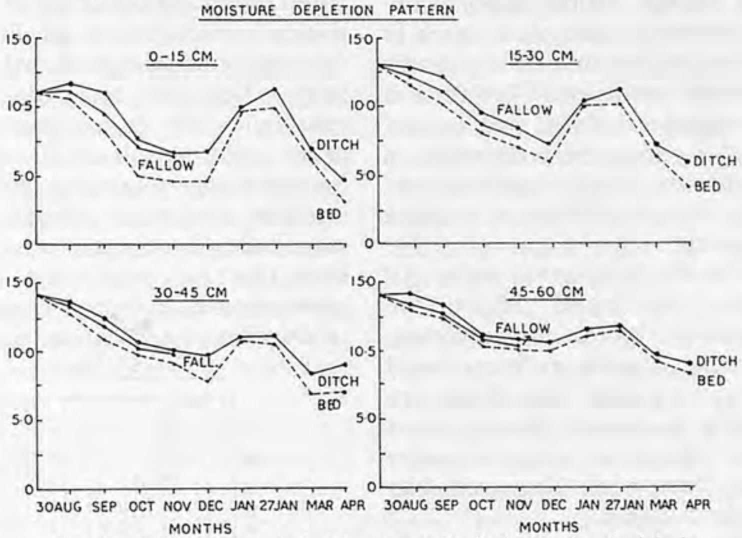


Fig. 3b. Soil moisture depletion pattern in ditches and raised beds vis-a-vis fallow under rainfed conditions at Delhi.
Source: Rajat De, B.B, Jurkhede and Ganga Saran (1973). Study in Progress at Indian Agricultural Research Institute, New Delhi.

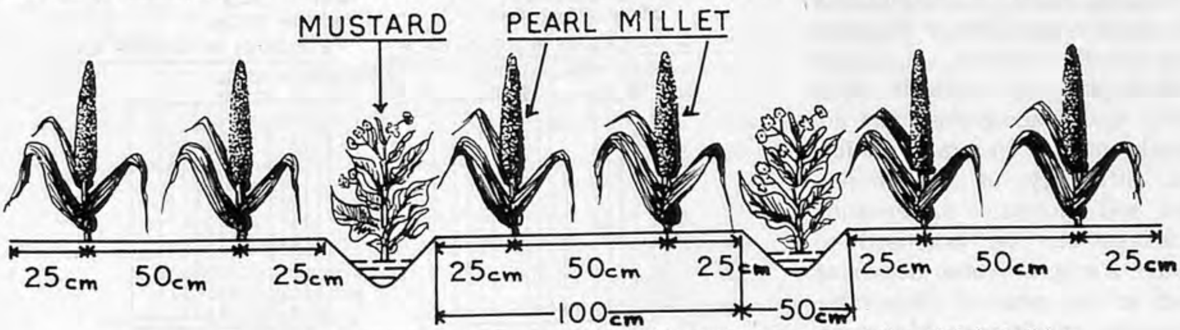


Fig. 3a. Methods of pearl millet and mustard planting grown in double cropping sequence under rainfed conditions.
Source: Rajat De, B.B. Jurkhede and Ganga Saran (1973). The Study in Progress in the Agronomy Division of the Indian Agricultural Research Institute, New Delhi.

Table 8. Performance of transplanted and direct seeded pearlmillet at the Indian Agricultural Research Institute, New Delhi, (De, Turkhede and Ganga Saran, 1973).

Method of planting	1970	1971	1972	Mean
Direct seeded	22.0	21.5	21.5	21.7
Transplanted	30.0	28.0	25.5	27.8
Difference	8.0	6.5	4.0	6.1

raised beds and fallow plots. The water collected in furrows is made use of to plant a mustard crop. The stability of their performance has already been indicated in **table 6.** The data on transplanted and direct seeded pearl-millet have been given in **table 8.**

These data lead to infer that the traditional techniques of crop cultivation warrant suitable tailoring to sustain high yields and also to open up the possibilities for multiple cropping in dry land conditions. The information gathered in a specific situation has though limited applicability yet serves an example to work to attain similar information under varying conditions. Therefore, it is recommended that such investigations should be undertaken in various dry land countries to explore the possibilities of multiple cropping.

A study in progress under All India Coordinated Millet Improvement Project where various planting patterns are being tested is an instance of efforts to modify traditional farming practices. Planting systems under study have been diagramatically shown in **Fig. 4.**

The level of plant density regardless of planting design has been kept constant (1,75,000 plants/ha) based on the research information gathered in different agro-climatic regions. It is felt that if planting in blocks or in wider row spacing does not adversely reflect on grain production efficiency of pearl-millet, then soil moisture conservation measures can be practised to sustain a crop in winter season at least in the rear of favourable monsoon conditions. Moreover, inter-cropping with non-cereals can also be practised to augment economic returns per unit of rain water, area and other capital inputs.

Fertilizer Use

In dry land conditions judicious fertilizer use serves an insurance against adverse conditions, since well fertilized crop has better moisture use efficiency. Possibilities of fertilizer placement at appropriate depth could also sustain crop in extended rainless/moisture stress periods. Singh (1972) tested various levels of fertilizers under rainfed conditions on pearl-millet, sorghum and red gram. Nitrogen application in pearl-millet (80 kg/ha) improved grain yield by about 10 q/ha. Sorghum also responded well to nitrogen application though the magnitude of response was less than that for pearl-millet. Red gram showed marginal response to phosphorus application. Barley and Mustard in winter season (grown on conserved soil moisture) recorded varying degrees of responses to fertilization. Placement of fertilizers appeared invariably superior to their broadcast application while foliar feeding failed to record further improvement over placement. Pearl-millet and sorghum, the chief dry land crops of India have recorded remarkable response to nitrogen application in different agro-climatic conditions. In fine, fertilizer use in dry land conditions undoubtedly pays. Therefore, it is recommended that doses, forms and methods of fertilizer application in dry land conditions should be worked out for individual crops as well as crop rotations. The residual fertility should be evaluated before planting of the next crop in the sequence. This could be accomplished by evolving suitable techniques to assess residual fertility.

Water in dry land conditions is chiefly received through precipitation and every drop of the same should be properly made use of. This would involve proper blending of available knowledge on soil moisture conservation, storage and working out of potential evapo-transpiration for

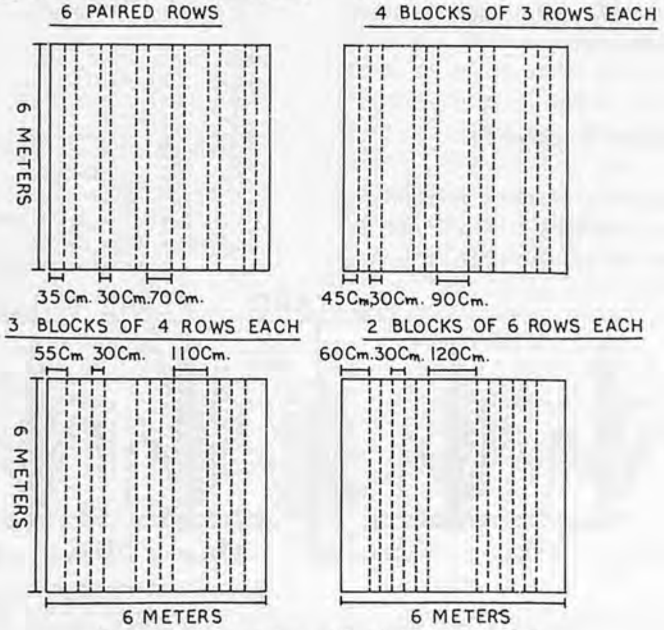


Fig.4. Planting systems with rainfed pearl millet.

different agro-climatic regions, vis-a-vis rainfall. Soil moisture conservation and rain water harvesting techniques deserve due decideratum. Bunding, strip cropping, canopy management, mulching and use of anti-transpirants may help a great deal in this regard. The probable soil moisture deficit should be ear-marked to plan for multiple cropping. Sreenivasan (1972) has gathered information for different states of India and a few of them have been presented in **table 1.** Similar information should be gathered and catalogued in various dry land conditions intending to follow multiple cropping. Such information would require studies on progressive soil moisture balance, moisture supply, consumptive use and rooting depth (Dastane, et al., 1970) **(Fig. 5).** This is an ideal work capable of providing lead to collect identical information in various agro-climatic regions.

In fact, the moisture use efficiency varies from crop to crop and in the All India Coordinated Dry Land Agricultural Project it has been observed that barley had almost the double water use efficiency than wheat and was closely followed by mustard (Sinha, 1972). Some important data gathered at Agra Centre (Uttar Pradesh) have been set out in **table 9.**

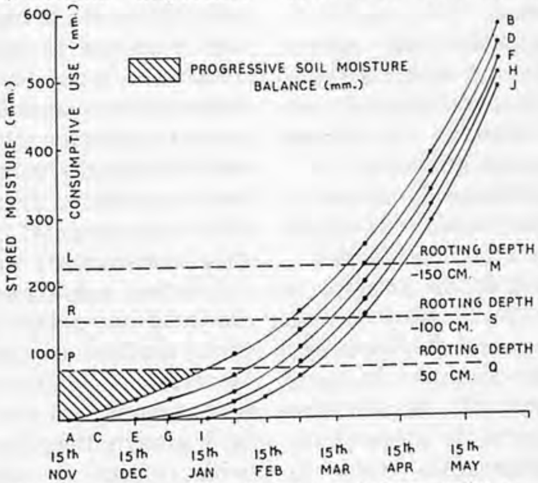


Fig. 5. Progressive soil moisture balance under a given condition of moistre supply, consumptive use and crop rooting depth.

Source: N.G, Dastane, M. Yusuf and N.P. Singh (1970), Paper presented in All India Seminar on Dry Land Farming held at New Delhi, Jan. 22-24 1970.

Table 9. Water use efficiency of various crops.*

Crop	Grain (q/ha)	Water use efficiency (kg/mm/ha)
Barley	23.15	10.60
Wheat	12.95	5.64
Mustard	20.80	9.53
Linseed	11.98	5.50
Gram	16.80	7.93
Lentil	8.01	3.69

* Source: S.K. Sinha (1972). Crop Selection for Water Use Efficiency. Indian Farming 22(2):62–63.

A perusal of these data would reveal that barley would be the first choice in moisture deficit areas while mustard and gram will constitute second and third choice Research information of this kind will help a good deal in crop selection and therefore, the authors recommend such investigations under dry land conditions to formulate appropriate cropping systems and patterns of varying intensity.

Implements

Suitable implements for land shaping and efficacious land lay out are very essential to achieve success in dry land regions so far as multiple cropping is concerned. The implements which can be used for subsoiling and placement of fertilizers in deep soil layers would be immensely useful. Water harvesting techniqued require the implements which can be used to provide the desired slope and shape to the cropped and uncropped area to attain high water yields. Storage of moisture in dry land conditions would naturally be done in the pits of varying sizes as per needs of cropping system which can not be made use of without appropriate machines. Dr. A.M. Michael of the Indian Agricultural Research Institute (Water Technology Centre) has developed various useful implements which can be used in dryland farming. Designing and development of appropriate prototype of implements for different soil conditions is the need of the hour in all dry land regions. The testing of the prototypes on extensive scale for their efficacy would constitute the primary step towards the mechanization of farming operations in these areas. The importance of these implements assumes added dimensions in the regions proposed to put under multiple cropping because expeditious operations in cropping systems are the basic ingradients of success.

Multiple cropping in dry land conditions, is by far, an uphill task yet it is not impossible provided technical know-how available in various disciplines of agricultural science is properly integrated for its practical utilization. The lacuna in the existing research information are to be identified and filled up through initiation of appropriate studies to execute multiple cropping programme in various countries /regions.

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Multiple-Cropping and Mechanization

Cropping Patterns and Irrigation Problems in Multiple Cropping

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Success in multiple cropping warrants suitable utilization of multi-disciplinary knowledge since any lecuna in technical know-how would retard the pace of progress. The necessary multi-necessities include crops and crop varieties, soil management, fertilizer use and other capital inputs but, scientific water management would largely dictate the success. Water is an essential input to execute any multiple cropping programme and if it's management is faulty, the possibilities of intensive cropping may be called off for good. Water management problems in multiple cropping patterns are multifarious and tedious to tide over without scientific approach. Some of the important of them have been listed below:

1. Continuous and indiscriminate water, apprication leading to problems of waterlogging and salinity.
2. Limitation of choice of crops due to unscientific irrigation management.
3. Determination of water requirement of various crop sequences and critical stage of growth for individual crops.
4. Development and demonstration of suitable prototypes of implements for land levelling to enhance water use efficiency.
5. Agro-techniques suited to specific needs to sustain levels of high production.

This paper is an attempt to touch upon the existing and anticipated irrigation problems with reference to multiple cropping. The authors will largely base their view points on the available research information under Indian conditions. This information, however, can be monitored to liquidate similar problems in any country of the world which has similarity to the specific instances quoted in the paper.

Multiple cropping in irrigated tracts involves knitting of two or three or four crops in a sequence and all of them are irrigated as per their water needs. The continuous use of water round the year in the tract/region indicates the recharge of ground water round the year. This water gets accumulated depending upon the natural drainage of the locality and will finally reflect on water table situation. Depending upon the environmental and adaphic conditions salinity may join hand to further aggravate shallow water table or waterlogging problem. Quality of irrigation and underground water and also the salt content in the soil profile will govern the time and space with respect to threat to crop production. This view point could be substantiated with the specific examples under Indian conditions.

The provision of irrigation in a particular cropping pattern caus-

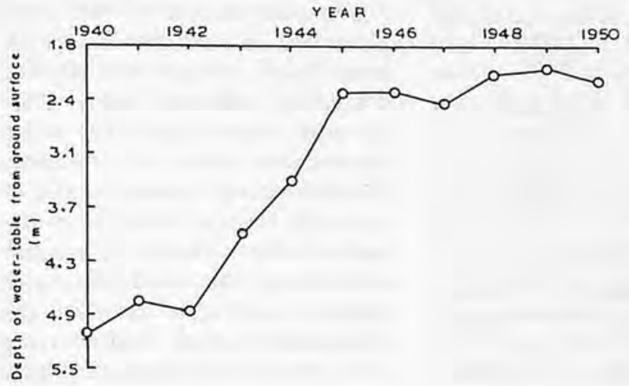

Fig 1. Average water-table readings on July 1 each year.

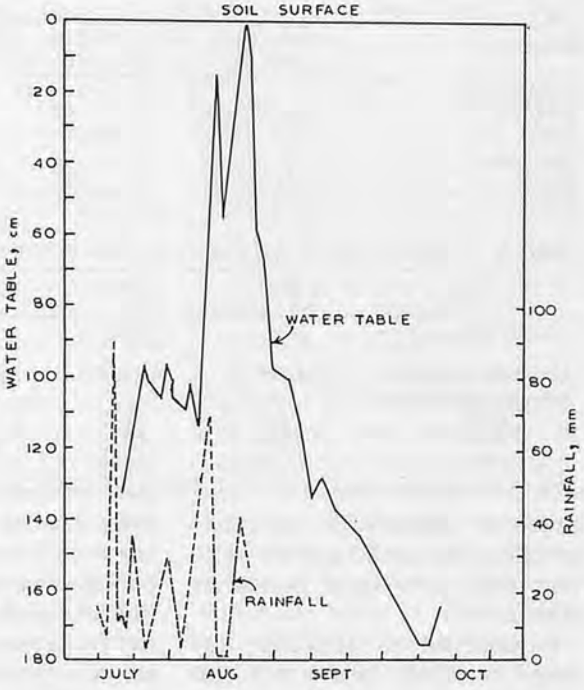

Fig 2. Hydrograph kharif 1968 crop-sorghum (CSH—1)

es slow and steady rise of water table. The studies carried out to follow the position of water table (1940 to 1950) in multiple cropped area postulated a continuous rise of water table, Dakshinamurti et al (1961). The relevant data have been graphically reported in **Fig. 1**. As is evident from the graph, the situation could have been either remedied or alleviated if adequate provision for drainage could have been simultaneously made. The lack of integrated approach has bred the problem and has largely limited the choice of crops in this area. The intensity of the problem increases by leaps and bounds during rainy season when the water table rises towards the surface and stays very close to it for fairly long period of time (**Fig. 2**). It is a tough task in such a situation to go in for profitable crop production. However, the crops having varying water requirement coupled with appropriate agrotechniques could be one possibility in the area. Normally, paddy is the only crop capable of growing on such lands. But, provision of suitable drainage and appropriate modification of cultivation methods made it possible to grow crops like sorghum, maize, and pearl millet in rainy season. These crops were followed by wheat, mustard, peas, linseed and barley etc. in the winter season. Thus double cropping could be successfully done in this problem area. The possibility of the short duration crop (in summer) is also bright. This brings a point at home that scientific management of water in multiple cropping goes a long way for profitable crop production. Information on the initial depth of water table is necessary to economise irrigation without losing crop yield. The irrigation water, thus saved, could profitably be diverted to the areas potentially suitable for multiple cropping. The management of underground and irrigation water is capable of enhancing the area under multiple cropping provided scientific approach is made to augment irrigation efficiency.

In 3 and 4 course rotations the total water requirement of the rotation will be fairly large. The crop will make use of only a part thereof and the remainder will either be lost through deep percolation or through evaporation. The former is important since it serves as a potential source to recharge the underground water. Therefore, provision of adequate drainage and possibilities to reduce irrigation requirement of individual crops through partial overlapping of growth periods may be worth examination. To illustrate, planting of toria (Brassica), carrot, radish and turnip in the standing crop of maize (nearing maturity) can reduce irrigation at least by one.

Besides water table, salinity in irrigated multiple cropping sequence may pose a problem which at times may be baffling and difficult to tide over. The authors' studies indicated that maize, sorghum and pearl millet, drown in double crop sequence gave no yield in saline and waterlogged fields. In fact, the evapotranspirational pull initiates the upward capillary flux of underground as well as externally applied water in such situations. The salts are, thus, transported and deposited in the root zone and soil surface which pose to threat to crop production. The date gathered under a similar situation are set out in **table 1** which bear monumental evidence to the above view point.

Zende (1972) reported the mag-

Table 1: Water table, salinity and performance of 2-course rotations on saline and waterlogged soils.

Sequence	Water table range (cm)	Salinity (EC mmhos/cm)	Grain (q/ha)
Sorghum-wheat		(or harvest)	
Sorghum	Surface 31.0	11.42	Crop failed
Wheat	20.0–52.0	23.10	7.0
Maize-wheat			
Maize	Surface 30.0	3.22	Crop failed
Wheat	20.8–58.7	9.61	6.9

Table 2: Position of salt-affected area due to canal irrigation in India.

Canal	Nira R.B.C.	Nira L.B.C.	Godavari	Pravari
Year of initiation	1926	1885	1912	1923
Irrigation area (ha)	52,920	45,312	31,776	22,800
Salt-affected area (ha)				
1930	564	3,892	5,092	3,275
1955	3,004	5,213	10,242	6,793
1960	2,030	5,252	8,070	7,526

R.B.C. = Right bank canal L.B.C. = Left bank canal

nitude of salt-affected area under different canals and the relevant data have been quoted in **table 2.**

Introduction of irrigation resulted in salinity problem in the areas. Therefore, appropriate techniques for water management are essential to sustain high levels of production and to obviate the emergence of such problems in future. Multiple cropping may not be possible in such areas without application of suitable technical know-how viz. provision of drainage, lining of canals and identification of suitable cropping pattern coupled with agro-tech niques.

——2——

Crop planning and cropping intensity depend upon the availability of water as well as the source of supply. The information on rainfall distribution, frequency and quality vis-a-vis potential evapotranspiration for a locality is inevitable for efficient water utilization and to sustain high levels of crop intensity and production without limiting the choice of crops. For example, the data on rainfall and evapo-transpiration have been quoted from Sreenivasan (1972) for two contrasting states viz. Assam and Rajasthan. The former is classified as humid while the latter as arid one. The data presented in **table 3** would reveal that rainfall is two times more than the potential evapo-transpiration in Assam. As such, a crop like paddy can be grown after paddy so far as moisture availability is concerned. On the contrary, the evapo-transpiration in Rajasthan is much higher than the rainfall and therefore, severely limits cropping intensity. The total quantity of rainfall will be inadequate for planning, unless its distribution and periodicity of probable occurrence of extended rainless periods with intensity and frequency thereof is known.

Various multiple cropping sequences and their total water requirement presented in **table 4.** The problem which are likely to crop up with the passage of time have been anticipated and discussed below.

Table 3: Rainfall and evapotranspiration in two meteorological sub-divisions of India.

State	Rainfall (cm)	PET (cm)
Assam		
North	232	114
South	256	120
Rajasthan		
East	31	184
West	71	155

The spectrum of cropsin such situations is limited viz. in Assam, West Bengal and Orissa, choice is limited to paddy alone in most of the cases. The crops having low water requirements like cereals and pulses are out of question. On the contrary, in Rajasthan where rainfall is meagre and scanty the available water sources are also limited, the choice will fall on crops having low water requirement. Moreover, the successful crops for this area should be drought tolerant and capable of extracting moisture from the deeper soil layers. It becomes difficult to conserve moisture for winter season crops and therefore, without external source of water mulitiple cropping in such areas appears an uptill task. But, the recent introduction of irrigation through Rajasthan canal has offered a wide choice of crops which can be knitted in multiple cropping sequences of varying intensities and water requirement. Introduction of multiple cropping in these areas is breeding the problematic situations in water management and call for an immediate solution.

Seepage and indiscriminate water use results in the rise of water table which is known to be wedded to a host of problems in crop production. Many experts while working in different areas substantiated the emergence of many irrigation problems. The prevailing state of affairs in these areas is an adequate warning to ward off cropping up of such problems in regions where irrigation is to be introduced.

In fact, the water requirement of individual crops in a mulitiple

Table 4: Cropping sequences and their total water requirements.

1.	Paddy-Paddy-Paddy	—	570 cm
2.	Maize-Potato-Onion	—	225 cm
3.	Maize- Berseem- Cowpeas (Fodder) (Fodder) (Fodder)	—	210 cm
4.	Maize-Turnip-Onion	—	155 cm
5.	Bhindi-Cauliflower-Tomato	—	145 cm
6.	Maize-Brassica-Green gram-Wheat	—	125 cm
7.	Pearl millet-Barley-Green gram	—	50 cm

sequence and for the proposed or prevalent cropping pattern (on locality basis) should be worked out and summed up. The possibility of regulating the total water needs should be explored. For instance, in maize-wheat-moong (green gram) rotation, planting of maize in standing crop of moong saves one irrigation which could be doubly advantageous. Since it would reduce the rate of recharge on one hand and on the other, can enlarge area under irrigation if diverted for other crops.

—3—

The usual practice of water application without proper measurement promotes irrigation problems on account of excess water use. Therefore, it becomes imperative to apply measured quantity of water at appropriate crop growth stages in multiple crop rotations (**table** 5) based on the total water needs, Michael et al (1970).

The information contained in **Table 5** stresses the need to gather indentical data on various crops and then it will greatly useful to select crops for appropriate multiple cropping sequences depending upon the availability and source of water. However, it appears equally essential to work out water requirement of different crops grown in various seasons and agro-climatic conditions for profitable multiple cropping without multiplying irrigation problems. Total water needs of a tract for a given cropping pattern could be reckoned and supply to irrigation water could be accordingly regulated to nip the problem-emergence in bud stage itself. This would ensure economy in water use and can augment irrigated area with the same available water. However, timely supply should be assured to avoid fall in crop production efficiency.

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In multiple cropping timeliness of farming operations play a dominant role. Therefore development of suitable implements for expeditious land preparation with a view to augment irrigation efficiency would constitute necessary necessity. The crops to be grown in a particular sequence will have varying water requirements and the reaction to irrigation management.

Levelling of fields before planting is essential for efficient water utilization since unlevelled field topography precludes uniform water application and reflects adversely on crop performance. Control of weeds through manul labour may not keep pace with the demands of the time schedule in multiple cropping. This could be expeditiously accomplished through mechanization which will improve upon irrigation efficiency and crop productivity. A specific example of maize-potato-wheat-green gram rotation has been discussed below.

After maize harvest there is only very small span of time available for seed bed preparation of potato. This cannot be timely done without mechanization i. e., preparation of ridges and furrows as well as seeding should be mechanically done to avoid loss of time. When potatoes have been dug, wheat sowing would again warrant expeditious planting which again would be done through the dint of appropriate machine to save time and to eliminate reduction in yield. The last crop of the system would be mong (grbbn gram). This crop should be sown in time using appropriate mechanical implements. In fine, mechanization would be the only way out for the success of cropping patterns involving intensive crop rotations.

Methods of irrigation for the crops in above system would be different. Therefore, the appropriate water conveyance devices coupled with suitable method would enhance the irrigation efficiency and economise water use. In potato, ridge and furrow method of irrigation is known to be suitable while in wheat check basin method is useful. These two methods would need different conveyance devices for efficient water use. Michael of the Indian Agricultural Research Institute (Water Technology Centre) has developed concrete channels of varying sizes capable of reducing losses and regulating flow according to needs. These channels have successfully been used in the multiple cropping block of the Institute.

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Agro-techniques to avoid irri-

Table 5: Irrigation schedule for different crops.

Crops	Sowing time	No. of irrigation	Water requirement (cm)	Critical stage	Time of irrigation after sowing
Wheat (Mexican Dwarf)	November (4th week)	5 to 7	45	Crown root Heading and Dough	20th 55th 75th 95th 110th
Barley	November (2nd or 3rd week)	2 to 3	30	Boot and Dough	30th 80th 95th
Peas	October (Last week)	1 to 2	15	Pre-flowering	55th
Potatoes	October (3rd week)	8 to 10	50	Bulking	1st 13th 25th 37th 49th 61st 73rd 85th 97th 100th

A field water course lined with brick masonry. Lining with suitable materials practically eliminates conveyance loses of irrigation water.

gation problems in multiple cropping system would chiefly involve land shaping, use of measured quantity of water at appropriate time depending upon edaphic and environmental conditions, use of fertilizers and selection of short duration photoinsensitive time-crop varieties.

Land levelling as indicated earlier plays an important role in uniform and efficient distribution of irrigation in a field. This in turn, eliminates the possibility of water wastage on the one hand and on the other ensures uniform crop growth. But, land shaping can be done with the help of suitable machines which should be made available even on hire to those who cannot afford to purchase them. Besides, levelling application of measured volume of water at optimum depth and stage of crop growth is equally essential to preclude the emergence of irrigation problems. The depth of irrigation for the crops included in a multiple cropping system should be known under given set of soil and climate conditions. In general, water sufficient to wet the effective root zone as estimated/decided on the basis of soil moisture depletion appears scientific way of water application. The critical growth stages for all the crops should be identified for scientific water management. For instance, in Mexican-wheat these stages have been defiend as indicated in **table 5**. This information will help a great deal in avoiding excess water use and therefore would nearly root out the problems usually associated with irrigation in a multiple crop sequence.

It is equally essential to provide for adequate underground drainage in the irrigated area under multiple cropping or else the continuous recharge of underground water level would result in rise of water table and soil salinization depending upon quality of irrigation water as well as salt status of the soil profile. Therefore, preventive measures and devices provided at the initial planning stage will eliminate the likely cropping up of irrigation problems in these areas.

Use of balanced fertilizers to the individual crops knitted in a multiple sequence is capable of augmenting water use efficiency. Thus, the economic optimum doses of fertilizers for all the crops should be known. Pandey et al (1970) have reported water use efficiency in relation to fertilizers. It was observed that use of fertilizers greatly enhanced the water use efficiency of wheat, cotton and potato etc. The method of their application also had a bearing in this respect. Placement was more efficient than broadcast. Thus, judicious fertilizer use realizes the maximum benefits of the irrigation water and makes the practice remunerative. This would also help in elimination of the low efficiency of irrigation, a common problem in multiple cropping and arable farming.

The problem in some multiple cropping areas is the shallow water table and fertilizer use in different course rotations was found to be very useful Pandey, et al (1972). Nitrogen use brought about 100-150 per cent increase in water use effifiency in wheat, barley and mustard. The magnitude of this influence even in rainy season crops was spectacular. This leads to infer that use of fertilizers tides over the problem of low irrigation efficiency and would be universely useful in a multiple cropping system. Since irrigation efficiency in intensive cropping is commonly low which reflects on economic returns per unit of water and hence the proposition possesses great potentiality to boost the water use efficiency in such situations.

REFERENCES

Dakshinamurti, C., Saxena, P. N. and Rao, E.G.K. (1661). Nature, 190 No. 4781 pp. 1100, 1101.

Michael, A. M. and Pandey, S. L. (1970). Time your irrigation for top yields. Intensive Agriculture, VIII: 3, p. 17-20.

Pandey, S.L., Pal, M. and Ray, S.B. (1970). Water use efficiency in relation to fertilizers. Fertilizer News, 15: 12 p. 75-80.

Pandey, S.L., Sinha, A.K. and Pal, M. (1972). Water table fluctuation and its interpretation. Symposium on water-logging. 44th Annual Session of Central Board of Irrigation and Power, New Delhi, p. 55-63.

Sreenivasan, P.S. (1972). Rainfall and evapotranspriration in relation to crops and cropping pattern. Indian Farming, 22(2): 38-42.

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Recent Trends in Water Management

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Introduction

India is one of the few countries in the world that has a monsoon pattern with four months rainfall and eight months droght. Taking the average rainfall of India round about 122 cm, the total water that we get in the form of rain on the entire subcontinent works out to be about 370 million hectare metres. 170 units of rain water received goes as runoff and flows through the rivers. About 120 units is estimated to be the loss due to evaporation. In the 80 million hectare metres that remain, only 37 units reach the ground water. In other words, about 10 percent of the rainfall is effective in recharging the ground water sources.

The surface water is either stored in big irrigation dams built for distribution through canals or is diverted from the water sheds into small village tanks that irrigate a few hundreds of hectares. The main sources of irrigation water thus fall under i) the canal and tank irrigation and ii) ground water irrigation. If the entire water received in the form of rain is harvested properly and used for judicious irrigation, the water is more than sufficient to raise successful crops throughout the year. Attempts are, therefore, being made to conserve every drop of water possible and maximize the yields with a given unit of water.

Althought the country has several big dams constructed with the engineering skill available, and distributed through lined channels as far as possible, the irrigation pattern from the canal mouth into the farmer's field has not been given adequate attention. Even in the highly developed agricultural states like punjab, the channels of irrigation through the fields are unlined and seep huge quantities of water. The total loss of irrigation water through these *kuchha* channels is estimated to be about 25 percent of the irrigated water. It is, therefore, a challenging problem to spread the technology of saving this water in all the rural agricultural areas and thus irrigate more acreage of the oultivated crops. In this connection, the Water Technology Centre of the Indian Agricultural Research Institute, New Delhi has perfected three units, i) a rectangular channel of one metre length, ii) a gate to control the water passing through the canal and iii) a tube through which the water can be carried. All the three unite can easily be constructed by a farmer in any village and the economics worked out to be about Rs. 3/- per metre in the case of canals. The farmer can easily constructs these in the off season and the life of these is expected to be atleast 10 years.

Rice Irrigation

A lion's share of the irrigation water in India, namely - 45 percent is at present being given to the rice fields. A minimum of 5 cm of standing water is usually kept on the surface of the rice soil. Rice is being grown throughout the length and breadth of our country on plains as well as high altitudes, on lands with low as well as high infiltrations. The data collected from different areas indicated that there is enormous variation of the water requirement of the rice crop varying between 150 cm and 350 cm of water depending on the type of the soil. It is very necessary that techniques to reduce the infiltration particularly on sandy loam rice growing soils, require to be worked out as to save water and use it more profitably for other crops.

It is well known that compaction of soil reduces infiltration considerably but it is difficult to put it as an agricultural practice on extensive areas and hence the method has its limitations. Scientists in Japan have succeeded in using a technique known as Bentonite field technique where a one centimetre thick layer of Bentonite gel is kept at a depth of 20-30 cm below the soil. To prepare this Bentonite field not only heavy equipment is necessary but also it works out too costly for a common cultivator in this country. A modification of this technique known as Bentonice-bed technique practiced at this Institute to seal the bottom of water tanks to reduce infiltration has recently been tried at the I.A.R.I. New Delhi rice fields. In this technique Bentonite equivalent to 0.5 percent of the weight of first 10 cm of the soil is mixed with small quantities of sodium chloride and washing soda and mixed with the entire 10 cm layer during the course of puddling of the rice field. The principle behind this is that Bentonite forms a gel along with the soil and reduces the infiltration. Preliminary experiments carried out at the I.A.R.I. indicated that the Bentonite field required 250 cm of water while 350 cm of water had to be used in the controlled field without Bentonite. This technique is being perfected not only with Bentonite but also with the addition of black cotton soils which contain about 50 percent of this type of clay in it. In other words black cotton soil can be substituted for Bentonite in suitable proportions.

Water Harvesting

The pattern and quantity of rain water received annually changes from one part of the country to another depending upon the geographic situation. Rain water gets cleared as runoff and infiltration on most of the soils. On the black soils, however, the problem is different. These clays swell on wetting, become impervious to water and easily get inundated. It is a fallacy to note that during the *kharif* season when the rain water is plenty, no successful crop can be grown on these soils, at places like Jabalpur, and when the rains cease a crop is possible with the residual moisture during the *rabi* season. On the other hand, on most of the alluvial, red and laterite soils, a crop is possible only during the *kharif* season, while a *rabi* crop is a gamble. Under both these conditions water harvesting methods require to be adopted with suitable agronomic practices as to grow a *kharif* crop preceded by a successful *rabi* crop.

On the black cotton soils it is very essential to remove the rain water by land preparation with suitable gradient and formation of ridges along the slope. The water that runs through the furrows can be collected just below the field of operation in suitably built farm ponds. Plantation of crops on the ridges helps proper root dovelopment by eliminating the ill effects of water logging. The water so stored can successfully be used for an irrigation or two during the *rabi* season. Implements developed at the Water Technology Centre to make suitable ridges on heavy soils were successfully used on the black soils of Madhya Pradesh ensuring a successful crop production, both during the *kharif* and *rabi* seasons. At the same time, every drop of rain water could be utilized by suitably storing it near the field itself.

Rainfed agriculture on alluvial, red and laterite soils poses a different type of problem. During the *kharif* season a successful crop is possible while the *rabi* crop is a gamble. These are soils only with a micro structure and do not retain sufficient moisture for a *rabi* crop. Deep ploughing or chiselling before monsoon ribs open the mouth of the soil, and increases the infiltration of water into the soil. Deep ploughing followed by plantation of deep rooted crops and deep placement of fertilizer result in improvement of soil structure permitting a better growth of the *kharif* crop and successful storage of soil moisture in the sub-soil layer for raising a good *rabi* crop. Water harvesting under these conditions also is essential. Techniques for harvesting maximum quantity of rain water from water sheds require to be perfected using indigenously available materials. Work on the design of storage tanks with impervious sides and bottom and use of anti-evaporants to decrease the loss of water by evaporation should be intensified for maximising storage of water.

More crop per drop

Every drop of water should be utilized with the utmost care for increasing the crop yields. Most of our farmers use the normal irrigation practices, where water is charged on area basis. The farmer indiscriminately uses this water when it is available in plenty and always over irrigates his crop, while those unfortunate farmers with their lands at the tail end of the canal do not get sufficient water for irrigation. Recent researches carried out at the I.A.R.I. indicated that the yield of crop decreases considerably both with over irrigation and under irrigation. The results clearly indicated that the quantity of water required at each irrigation should be determined in consultation with the soil - the doner, and the plant-the user.

(Continued on Page 30)

Multiple-Cropping and Mechanization

Pest Control and Multiple Cropping

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Multiple cropping is not a new technique in crop production. In varying degrees of sophistication it has been practiced for many years in tropical areas of the world. In Latin America beans are planted in corn and encouraged to grow up the corn stalks. Corn and sorghum are often planted at random in upland rice fields. In Asia carrots, onions, cabbage, corn and other vegetables are often planted together. Mixtures of annual and perennial crops are common in much of the tropical world. Wile there are usually sound reasons behind these age-old practices, it often appears to be a rather haphazard method of crop production.

A new crop-production system is being developed for the tropics under the general name of "multiple cropping". The system is being designed to produce more and better food in areas where land is scarce and population pressure is high. Optimum use of available resources is the principal consideration of multiple-cropping proponents. The major resource is a full 12-month growing season. A cropping system which will provide nearly continuous ground cover is the goal and is accomplished by manipulating planting dates and crops. In so doing, maximum use is made of available sunlight and moisture. The ground cover also serves to protect the tropical soils from deleterious effects of sunlight and erosion.

A pessimist might decide quickly that multiple cropping is a step backward and will result in an insect-ridden tangle of weeds and diseased crops. Such could easily be the case. Tropical conditions are ideal for growth and spread of weeds, insects, and diseases. It is difficult enough under a monocrop system to provide good pest and weed control. Can the problems help but be more complicated when two or more crops are grown side by side? Probably not, but this should be accepted as a challenge, not a deterrent.

Potential problems of multiple cropping are numerous and varied. There may well be situations where one crop serves as a host to diseases or insects which will plague another crop. Under continuous cropping, plant life is provided year around for insects and diseases. New varieties may be more susceptible to local pests than native varieties that have been selected for resistance over the years. Pesticides normally used to combat such problems may be harmful to other crops in the system. Phytotoxicity is not generally a problem with insecticides and fungicides but there are a few exceptions. Cultural practices which are ideal for one crop may encourage diseases or other problems in a companion crop. Water management appears to be a potential problem in this regard.

On the other hand, there may be unforseen benefits from continuous cropping. Certain plant pathogens live on dead and decaying plant tissue. If mature plants are removed to make room for oncoming plants or new seedlings, host tissue for these pathogens would be reduced. The annual reinfestation of weed seeds during the nonproduction period would be halted. Plant nutrients in the soil would probably be used more efficiently than in a single-crop program.

Weeds are traditionally controlled by hand labor in much of the tropical world and this method will probably continue to be widely used under multiple-cropping systems. However, under high-rainfall conditions it is often impossible to effectively control weeds by hand. Too often the damage is already done by the time the fields are dry enough for weeding. Also one of the goals is to keep a maximum cover of crops which makes hand weeding more difficult than under the traditional row spacing. Under a family farm situation hand weeding may prove to be a poor use of limited labor.

The multiple-cropping system calls for more or less continuous planting and harvesting. Some of these practices lend themselves to mechanization, but the equipment will need to be small and hand operated. The end result is a more uniform demand on family labor. Under these conditions herbicides may prove to be a good replacement for hand weeding.

Herbicides, of course, can also kill crops, both by direct application and through residues in the soil. Great care will be needed to determine the correct herbicide and the correct time, method, and place of application. Conveying these principles to farmers will be extremely challenging. Band and directed applications will probably be more common than broadcast treatments. A band of herbicide over the row at planting time will protect the crop during the first 3th 6 weeks, yet will not harm other crops already growing nearby. During the later stages a herbicide can often be applied around the base of certain plants to kill late-emerging weeds. Most herbicides do not last long in the soil under tropical conditions. Nevertheless, herbicide residues may be of some concern when planting crops such as sweet corn or green soybeans which will be harvested in as few as 60 days.

Perhaps mulches and shields can be used to protect nontarget plants from phytotoxic pesticides. Use might be made of the adsorptive qualities of charcoal or activated carbon to keep chemicals away from sensitive plants. Soil fumigation before the initial planting, although expensive, may prove to be helpful in reducing weed, insect, and disease problems. Of course any practice which gains acceptance must prove to be economically sound. Even then it may not be feasible if the cash outlay is great.

I feel that basic background information is now available on the interaction between chemical pesticides and plants. The challenge remains to use the knowledge to best fit the pesticides into a multiple-cropping system. ■ ■

(Continued from Page 28)

Investigations carried out at the I.A.R.I. indicated that maximization of yield with a given unit of water is possible only if we irrigate the soils with just that much of water to bring the root zone to 3/4 field capacity of the soil (field capacity can easily be determined in any laboratory). Using this technique it is shown that the wheat crop which was normally considered earlier to need about 46 cm of irrigation water would only require about 20-25 cm of water for maximised yields. Just about 1/2 of what was being given earlier.

The techniques of irrigation are fast changing. The latest techniques of drip irrigation developed earlier in the foreign countries has now been made possible in our country with the construction of drip units at the Water Technology Centre, I.A.R.I. In this system the nutrient water is delivered just in the rhizosphere - the quantity of water delivered can be controlled and made equal to the evapotranspiration of the crop, i. e., the minimum water required for its successful growth. The economic of this technique is being worked out at different stations in our country with a view to put it on a firm basis in areas where every drop of water counts. In the areas where the water is slightly saline and should be used in smaller quantities for better soil management, drip irrigation is the best of the systems of irrigation studied.

Water Technology Centre has different facets of study, the common aim of all these being to utilize water judiciously for maximisation of crop yields. Scientists of different disciplines are interacting at this Centre with the common objective to perfect the technology. It is water but not land that will be the limiting factor in future agricultural production and economic grown of our country. Our final goal is the increase in production per unit of water or more crop per drop. ■ ■

Design Considerations of Harvesting Equipment in Multiple Cropping

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An essential component of a successful multiple cropping programme is the development and introduction of suitable equipment for timely and efficient operations on the farm. Traditionally it has been regarded that in a cropping year there are two periods of peak demand for labour or energy. These are, the cultivation and harvesting periods. Furthermore, it was generally accepted that the demand for labour particularly in tropical and sub-tropical zones is greater during the former than the latter due to climatic conditions. Consequently much attention and research was devoted to overcome this bottleneck by developing improved implements for ploughing, seedbed preparation etc., and introducing new crop varieties with different sowing dates without affecting the yields per hectare. Furthermore, it was commonly argued that bringing more land under cultivation and introducing high yielding varieties, multiple cropping and even relay cropping would enhance the employment opportunities and thus reduce the disguised unemployment problems faced by the majority of densely populated developing countries with labour surplus economies. Regarding developing countries with low population density a common belief prevailed till very recently among those concerned with agricultural development, the application of advance technology, i. e. capital rather than intensive. Unfortunately much attention has not been paid for the development of harvesting machinery for grain crops in developing countries. An example often cited is that the amount of man/day required to harvest an acre of wheat has been reduced from more than seven per day at the turn of this century, to nearly 0.2 man day at present, through the use of modern technology and combine harvesters.

Choice of Type of Equipment

There seems to be two possible ways of overcoming the problem of labour shortage during harvesting season and obtaining timely operation to facilitate the growing of the succeeding crop in the multiple cropping sequence. These are namely, (a) the use of combine harvesters and (b) development of improved simple harvesting machines suitable for the developing countries. The introduction of combine harvesters and their use in developing countries where traditional farming systems are in existence has been subjected to several handicaps specially because of land fragmentation, unavailability of suitable road networks, lack of skilled labour etc., which result in high cost of using combine harvesters which is common knowledge to all concerned with agricultural mechanization. On the other hand, the second alternative, i.e. development of simple harvesting machines suitable for average size farms in developing countries has unfortunately received little attention with a few exceptions in Japan and U.K.

Systems Engineering Approach in Developing Design Criteria for a Harvesting Machine

To solve the problem of harvesting emphasis has been given either to the technical aspects or the organizational ones only. This approach resulted in only limited success a more integrated approach which takes into account both these two aspects will lead to a better result. This is because it will enable the designer to realize the importance of the non-technical factors most of which are unquantifiable and at the same time make those concerned with the mechanization and organization aspects more aware of the technical factors the designer is forced to contend with. Such an understanding on both sides is believed to be beneficial to all parties concerned particularly the end user, i.e. the average farmer or peasant in a developing economy. This is possible through replacing the traditional piecemeal approach by an overall one. That is, the systems engineering approach.

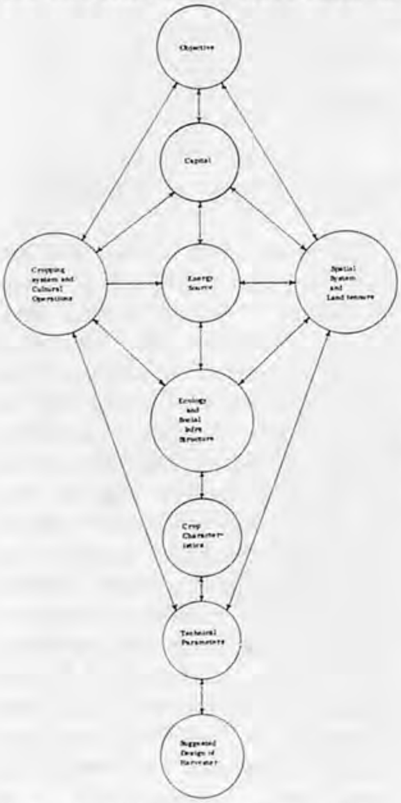

Fig. 1. Baloon diagram showing the main factors to be considered and their interactions in developing the optimum design of a harvesting machine.

The most dominant crops in a multiple cropping programme are wheat, barley and paddy. The effective design of harvester for grain crops will be the one that attempts to optimize the overall objective of the systems in question, i.e. a harvester capable of harvesting wheat in the most efficient way. The baloon diagram presented in **Figure 1** helps to indicate the main factors to be taken into account and their interaction which should be reckoned with. These factors are capital, energy source, ecology, social infra-structure, the cropping system and cultival operations, spatial system and land tenure, crop characteristics and the technical or engineering parameters or considerations.

With the systems approach being applied to a situation under consideration a systematic, concise, accurate and detailed analysis of the various factors can be made so that:

a) the component sub-systems, their nature and interactions are fully recognized and consequently their objectives can be precisely defined.

b) several alternative systems can be tested to determine which one is the most suitable to achieve the set objective (s) in the most effective manner.

Accordingly, while considering the design of a harvesting machine not only the technical aspects of the machine such as power requirement, design and strength of each component, reliability, service and life etc., are to be kept in mind but also the entire interface of the man-machine system, the related human effort to work with the machine thus introduced, the expected returns, e.g. can the farmer justify without loss owing the machine. Will the machine fit into the present system of his cultural practices without bringing about any radical changes, without replacing much of the power requirement and yet meeting the peak labour requirements at the time of harvesting when one faces labour shortage. Will it be to use it continuously and adopt to the changing farming conditions.

In a farming system, capital is invariably scarce and is a limiting factor to the introduction of any machine or practice which will require initial heavy capital investment. Advanced mechanized systems are capital intensive and to suggest an expensive machine will not stimulate the farmer to go for it, even if one is convinced that the machine may minimise considerable losses in his produce and save time and drudgery. He would prefer to limit his production or reduce the area he cultivates to the extent he can manage through the traditional way. The machine itself must not be very costly, otherwise a farmer will not be able to afford it though he would like to use it, and cost will become a limiting factor. Consequently, productivity will not be increased and will remain at its existing low level. In other words, one would fail in achieving the basic objective of the system.

Not only is the initial cost of the machine a factor coming in the way of introducing the machine, but also the facilities of repair and servicing by the agricultural machinery dealer. They have the problem of justifying a service specially when they face low density of machine in a particular area, long distances from their headquarters, poor and impassable roads to villages, lack of materials, government restrictions on imports, taxes and lack of trained personnel. Inadequate service facilities is a major hindrance to efficient introduction of any machinery. The best solution to such a situation seems to be to introduce a machine which will require minimum maintenance and service and parts which are easily available or preferably locally manufactured. The advantage of timeliness afforded by us of the modern machine is lost if in case of a breakdown, immediate repairs cannot be undertaken and the farmer is faced with a greater financial loss than if he had adhered to the traditional method.

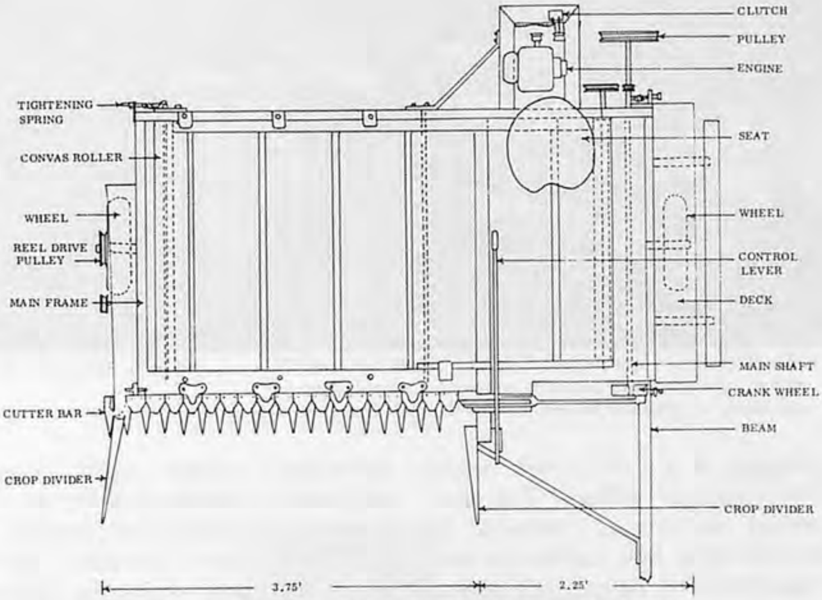

Fig. 3. Plan view of Pusa reaper with the reel removed.

The total width of the machine is a factor in view of the infrastructure. Field movement over irrigation channels and bunds, farm to farm transportation and above all storage during the rest of the year when the reaper will not be in use has to be kept in mind. The village lanes are usually 7'—8'. This limits the width of the machine not to exceed about 6 ft. The present labour shortage during harvesting is bound to become more acute in future as multiple cropping practice becomes more widely spread and agricultural inputs easily available. Consequently as mentioned above, any realistic solution to this problem requires an overall and integrated appraisal of its many aspects, e.g. ecological, cultural, operational and socio-economic. It is being realized that systems analysis techniques have a valuable contribution to the solution of this type of problem.

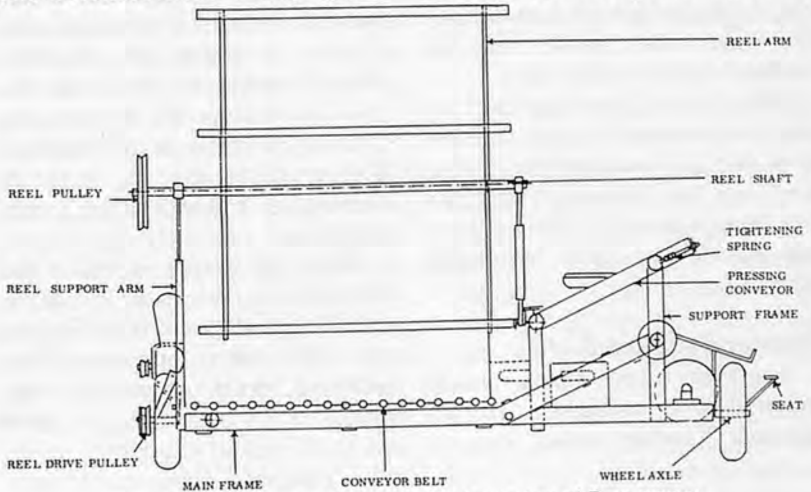

Fig. 2. Line diagram illustrating the front view of Pusa reaper.

Development of Pusa Reaper

Careful investigations on the techno-economic, agro-climatic and other requirements enumerated above with special reference to average from situations in India lead to the dovelopment of the Pusa reaper. Pusa Reaper was an attempt to overcome many of the difficulties faced by the reapers developed earlier. The few imported reapers which were tried at different places were not accepted by the farmers due to high cost, heavy draft, inefficient and difficult reaping mechanism, difficulty in bundling and poor manoeuvrability. They also did not result in a substantial reduction in labour requirement in harvesting. These machines designed for horses were too heavy for a pair of average size bulloks.

Several attempts were made to develop a reaper which would overcome the above mentioned problems. The main frame of the Pusa reaper is supported on two small wheels with pneumatic tyres. The conventional mower cutter bar has been adopted to form the cutting unit. The length of the cutter bar was 1.5 metres. The crop is cut by reciprocating knives, assisted by a multi-arm reel which is driven by a belt pulley drive from one of the ground wheels. The cut crop is received on a moving endless platform which delivers it to one side of a machine. The platform

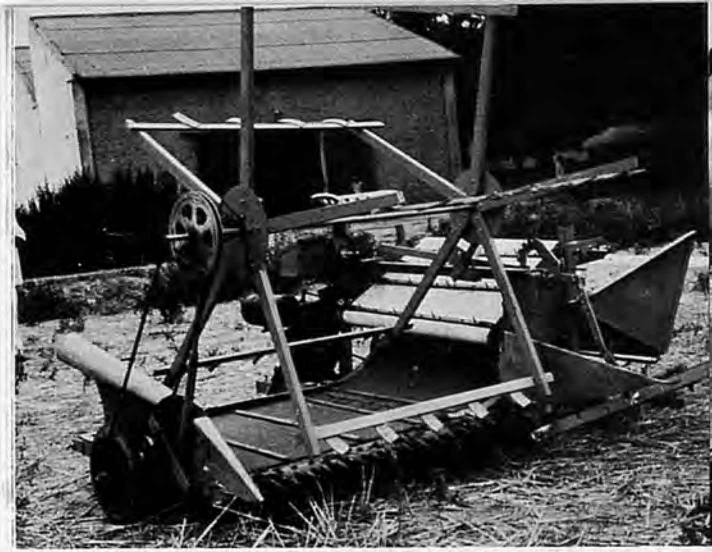

Fig. 4. Front view of Pusa reaper. Note the cutter bar, reel, canvas conveyor and pressing conveyor, control lever and beam for hitching the machine to the bullocks.

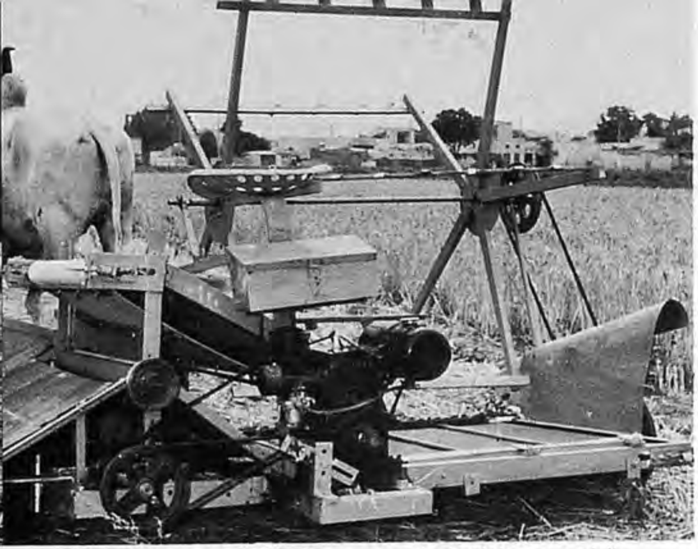

Fig. 5. Rear view of the Pusa reaper (animal-drawn model).

consists of a canvas belt driven by a pair of rollers. The horizontal platform is continued by an elevating belt carrier consisting of a lower carrier belt and an upper pressing belt. The elevating belts are fixed at an angle of about 30 to the horizontal. The elevating belt, assisted by the pressing belt, receives the cut crop from the horizontal platfom, raises, it and delivers it into a collection deck. The harvested crop is collected in the form of bundles in the deck. When the deck is full it is unloaded on the ground by tilting a flap board which forms the outer side of the deck. The bundles are tied by manual labour. By removing the collection deck it is possible to spread the cut crop in rows without forming the bundles. This eliminates the need of an operator to handle the deck board. Spreading the crop in rows without bundling has been found advantageous when the crop growth is thick.

Working of the Reaper

The reaper is pulled by a pair of average size bullocks. A wooden beam, provided in the front, is used for hitching to bullocks. The power for operating the cutting mechanism and the conveyor belts are provided by a small light-weight engine fixed to the rear of the machine. It was observed that a two or three-horse power engine was sufficient to provide the necessary power for cutting and reaping. A V-belt drive provided the necessary speed reduction from 1500 rpm of the engine to 400 rpm at the crank wheel to which the pitman head was fixed. This produced 800 strokes per minute of the knife bar. The entire machine is dynamically balanced.

Two men are required to operate the machine; one man to control the bullocks and the other for unloading the collection deck. Another two men are required for tying the bundles. Separate seats are provided for the two operators. When the bundling attachment is not included in a single person can operate the machine. A control lever is provided near the operator's seat by which the cutter bar can be raised and lowered when negotiating ridges and field channels. A clutch is provided to engage and disengage the power of the engine from the cutter-bar.

About 2 to 2.5 hectares of land can be harvested by the machine in a day of 8 working hours. The area can be increased when the machine is used for longer periods during the peak harvesting season.

Tractor-Operated Model

The Pusa reaper may be easily adopted for operation with a tractor. Tractor power can be used to pull the reaper and operate cutting and reaping mechanisms. This eliminates the need of the engine. The modifications needed are adopting the beam for hitching to the tractor draw bar and a drive with a telescopic shaft with a universal joint to transmit the power from the tractor power-take-off to the crank wheel of the reaper. A gear box containing two spur gears provide the speed reduction at the crank wheel. When operated with tractors it is possible to increase the length of the cutter bar to about 2 metres.

The Pusa reaper is a low cost, light weight compact machine suitable for medium and large size farms. It makes the harvesting operation easy and efficient. The manual labour required in harvesting is greatly reduced. It overcomes the many difficulties met within the operation of the reapers developed hitherto. Timely harvesting of crops will reduce shattering loss and the risk of damage to the standing crop by rain, birds and animals. The machine can be used for harvesting wheat, barley, oats, paddy etc.

When the reaper is not in use the engine used with it can be unbolted and used for carrying out other farm operations like pumping, threshing and chaff cutting. ■ ■

A Case Study of the Economics of Multiple Cropping in Delhi State

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Growth of human population at an unprecedented rate is baffling almost all countries in East. India too, faces the problem to feed her increasing population. Population of India in 1971-72 mounted to 582 million people. It has been estimated that per capita annual expenditure at Rs. 170. 80, at the 1960-1961 price index, can provide about 2000 calories per day per adult, a minimum need. The average size of holdings in India is usually about 2 hectares or less and the income therefrom is much below the minimum desirable for the nation as a whole. Inspite of the rapid growth of industries in India, the rural population will account for about 70 percent of the total population since 1951. The well-being of the rural population can be improved by augmenting productivity per unit of arable area and time.

During the recent years, agricultural scientists have developed short duration, dwarf, fertilizer responsive and photo-insensitive crop varieties. It has destroyed the traditional barriers and opened up the possibilities to grow three or even four crops for calender year where only one or two could be grown before.

The following discussion would throw light on the economics of various crop rotations tested in the union territory of Delhi. Multiple cropping boosts not only financial returns per hectare of land per year but also, generates enough employment for the unemployed rural masses since the system is labour intensive.

Demonstration on Multiple Cropping

The demonstrations on multiple cropping were initiated in Delhi area by the scientists of the Indian Agricultural Research Institute, New Delhi during 1967-68. An inter-disciplinary approach has been followed in planning and execution of the demonstrations. The important objectives of these demonstrations are the use of intensive cropping, balanced fertilization, techniques of soil and water management to protect soil productivity for posterity, the use of indigenous improved machinery and plant protection measures.

National Demonstrations Programme initiated by the Indian Council of Agricultural Research, is the first line of demonstrations of new agricultural technology on the cultivators' fields by the scientists aiming at maximization of agricultural production per unit area, inputs and time.

The demonstrations are carried out on 36 plots of about half hectare each so at to cover the entire rural area of the territory of Delhi. The demonstration plots were laid out on the farmers' fields who are the actual cultivators owning small holdings so that the high yields obtained are not attributed to the effects of affluence. Fertilizer requirement of each crop on individual demonstration were based on acaual soil and water analyses. The inputs and operations of these demonstrations are according to the recommended package of practices developed in the Institute.

Cost and Return Analysis of Crops

The cost of production of individual crop during 1972-73 and their economic returns are presented in **table 1.** The data represent the average production of individual crops grown, either singly or in a specific multiple cropping system. The net return per hectare have been worked out according to five different parameters in order to examine individual cases from different angles. Climatic conditions of Delhi permits selection of multiple cropping sequence from a cafeteria of crops. It is, therefore, desirable to examine the crops individually for an appropriate combination of multiple cropping sequence suited to a set of conditions. Some basic climatological data of Delhi are presented in **table 2.** The highlights of the yields of individuall crops are as follows:

Paddy: It is not the principle crop of the area, however, it is an important crop and grown in areas of heavy soils, high water table and adequate irrigation facilities. The average yield of 50.39 quintals per hectare is from the high yielding varieties; Pusa-2-21, Improved Sabarmati and Ratna. On an average, the total cost of cultivation of one hectare amounted to Rs. 1373.92 and resulted in a net income of Rs. 1459.80 per hectare.

Bajra (Pearl Millet): The crop is suitable for light soils and has low water requirements **(Fig. 1.)**. The grains are normally consumed by rural masses and the straw used for fodder of domestic livestock. The average yield of 34.20 quintals per hectare was obtained from 20 demonstration plots under Hybrid Bajra-3. On an average, the total cost of cultivation amounted to Rs. 942.21 per hectare resulting in a net profit of Rs. 1849.89 per hectare.

Maize: The average yield of 24.03 quintals per hectare was ob-

Table 1: Cost and return analysis of major crops in Delhi (1972–73)

Sl. No.	Crop	Period of Growth (days)	Average yield (g^1/ha)		Value of crop Rs/ha			Cost of production Rs/ha				Net return Rs/ha				
			Main product	By-product	Main product	By-product	Gross	Cash[1]	Family human labour	Family bullock labour	Total[2]	Per Quintal of grains	Over cash expanses	Per rupee return of cash expanses	Per day of crop stand	Per hectare
	Monsoon season crop *(Kharif)* (July to October)															
1.	Paddy	115	50.39	54.35	2670.76	1635.05	2833.72	1028.12	197.60	148.20	1373.92	28.73	1805.60	2.76	12.69	1459.80
2.	Millet *(Bajra)*	83	34.20	91.11	1881.00	911.10	2792.10	486.79	200.19	255.23	942.21	34.45	2305.31	5.74	22.29	1849.89
3.	Maize	93	24.03	53.09	1321.65	530.90	1852.55	819.06	207.48	116.09	1142.63	17.45	1033.49	2.26	7.63	709.92
4.	Reg gram (Arhar)	163	17.71	37.83	2125.20	189.15	2314.35	582.85	202.53	222.30	1007.70	68.10	1731.50	3.98	8.02	1306.65
	Winter crop *(rabi)* (November to April)															
5.	Wheat	–	51.56	56.14	3918.56	561.40	4479.96	1222.37	231.21	120.70	1574.28	55.47	3259.59	3.67	20.61	2905.68
6.	Potato (1971–72)	69	310.00	–	9300.00	–	9300.00	2626.54	515.76	–	3142.30	19.86	6673.46	3.55	89.24	6157.70
	Summer crop (April to June)															
7.	Green gram *(Mung)*	73	6.37	–	1274.00	–	1274.00	332.32	163.73	31.76	527.81	117.14	941.68	3.83	10.22	746.19
8.	Cowpea (Grains)	72	9.43	20.00	1650.25	100.00	1750.25	222.35	110.66	51.87	384.88	139.19	1527.90	7.87	18.96	1365.37
9.	Cowpea (Green pods)	83	40.20	49.38	3015.00	246.90	3261.90	456.90	219.25	85.22	761.36	61.06	2805.00	7.14	30.13	2500.54

1. Includes interest on cash expanses. 2. Does not include fixed costs like depreciation and interest on fixed capital. 3. Data pertains to the year 1971–72.

Source: National Demonstrations (1972–73), I.A.R.I., pp. 68.

Table 2: Climatological data of Delhi.

	June	July	August	September	October	November	December	January	February	March	April	May
1. Rainfall												
Normal (mm)*	44.5	222.2	209.8	146.0	30.8	0.0	5.6	18.8	16.8	17.0	5.6	14.6
1972 (mm)	5.6	310.3	133.7	74.3	13.0	68.4	0.0	5.0	22.8	20.5	19.6	0.0
1973 (mm)	9.0	105.9	N.A.	N.A.	N.A.	N.A.	N.A.	34.0	0.0	0.0	0.0	16.2
2. Temperature												
Max. (°C)*	39.7	35.0	32.9	33.3	32.1	27.6	22.2	20.2	23.2	26.0	36.0	39.9
Min. (°C)*	27.6	26.6	25.8	23.6	17.2	6.7	6.2	5.8	7.7	12.8	18.9	24.0
Average (°C)*	33.7	30.8	29.4	28.5	24.7	17.2	14.2	13.0	15.5	24.4	27.5	32.0
3. Evaporation (Standard 'A' pan) mm/day*	14.3	9.2	6.3	6.6	5.8	4.1	2.6	2.4	3.8	6.1	10.4	13.5
4. Sunshine hrs/day*	7.2	6.1	5.9	7.2	8.7	8.1	8.0	7.5	8.3	8.0	8.9	9.3

* Average of 30 years (1942 to 1971) N.A. : Not available Source : Division of Agricultural Physics, I.A.R.I., New Delhi.

tained from hybrid maized Ganga-5 variety. The cost and return analysis reveals the net profit of Rs. 709.92 per hectare after incurring a total cost of Rs. 1142.63 per hectare.

Arhar (Red gram): In context to multiple cropping *arhar* plays a prominent and vital role as it fixes atmospheric nitrogen, resulting in enrichment of the depleted soils. This is an essential crop for India, as it is the main constituent of the food of the masses. Pusa Ageti arhar variety evolved at the Indian Agricultural Research Institute, New Delhi is a short duration variety of about 163 days as against the earlier varieties of over 200 days. A special feature of the variety is to stand partial moisture deficiency during its growth period.

Pusa Ageti *arhar* resulted in an average yeild of 17.71 quintals per hectare giving a net profit of Rs. 1306.65 per hectare with a total cost of production of Rs. 1007.70 per hectare.

Wheat: Wheat is the second important food grain crop of India (**Fig.** 2). Green revolution in agriculture is the result of high yielding dwarf varieties such as Moti, Sonalika, Sharbati Sonora, Kalyan Sona, Hira and a few more. These dwarf varieties are non-lodging, disease and pest resistant, short duration and high yielding. Wheat is the most important and most widely grown crop of the area. It is the main crop of almost all the multiple cropping sequences.

An average yield of 51.56 quintals per hectare was obtained from 33 demonstrations of high yielding wheat varieties laid out under assured irrigated conditions and with the recommended package of practices. The average net profit per hectare was Rs. 2905.68 with a total production cost of Rs. 1574.28 per hectare.

Potato: Potato is the main vegetable cash crop of the area and forms an important constituent of the normal meal. Potatoes are preserved in cold storage resulting in remunerative benefits throughout the year. The crop resulted in a net profit of Rs. 6157.70 per hectare after an investment of Rs. 3142.30. Potato is most profitable considering the net returns per hectare and also net returns per day of crop stand.

Green Gram *(Mung)* : It is a pulse crop and is complementary to the staple food. *Mung* varieties grown in India are not free from mosaic virus diseases, insect pests and are also susceptible to water-logging conditions. The weeds also supresses plants growth and results in low yields during monsoon season. A recent-

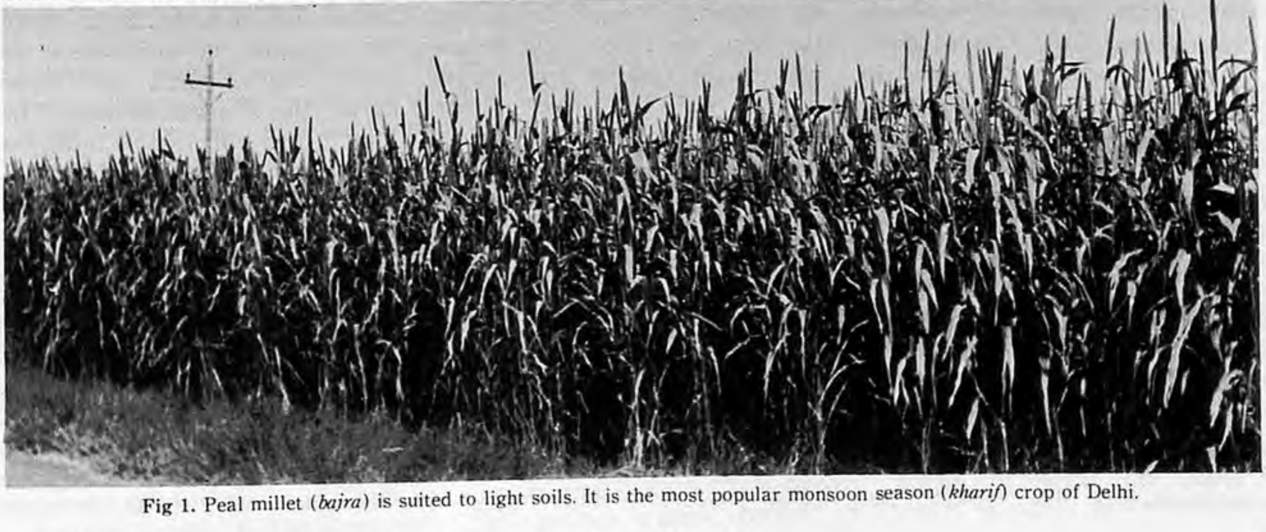

Fig 1. Peal millet (*bajra*) is suited to light soils. It is the most popular monsoon season (*kharif*) crop of Delhi.

Fig 3. Cowpea is a promising monsoon season *(kharif)* crop. The crop when raised for green vegetable, yields much higher economic returns as compared to the returns from dry seeds.

Fig 2. Wheat is the most important winter season (*rabi*) crop of Delhi State. It is invariably incorporated during *rabi* n almost all the multiple cropping sequences.

ly evolved variety at the Indian Agricultural Research Institute, New Delhi, named 'Pusa Baisakhi', when grown in monsoon season is not successful, however, flourishes during summer month viz. April to June. This crop variety is, therefore, able to fill up a vital gap in the multiple cropping sequence. Mung is sensitive to high salt contents and should not be grown on saline soils and waterlogged conditions.

The average yield of the demonstrations was 6.37 quintals per hectare. Total cost of cultivation of the crop amounted to Rs. 527.31 per hectare and the corresponding gross return was Rs. 1274.00, thus leaving a profit margin of Rs. 746.19 per hectare.

Cowpea: This crop is suitable to grow for grains and also for green pods as vegetable-Cowpea variety (**Fig.** 3). ,Varieties 'Pusa-do fasli' and 'Pusa Phalguni' grown for grains gave an average yield of 9.43 quintals per hectare resulting in a net profit of Rs. 1365.37 per hectare with an investment of Rs. 384.88 per hectare. Pusa-do-fasli variety when grown for vegetables gave a net return of 2500.54 per hectare. The vegetable crop is thus more remunerative and can be profitably adopted provided the crop has a ready market.

The economic analysis of various crops in **table 1** reveals that the most remunerative crop is cowpea (grains) considering per rupee return of cash expanses. It shows that every rupee spent will realise Rs. 7.87 while considering the returns on cash investment, the gains per rupee spent following cowpea (grains) are; cowpea (green fodder), *bajra, arhar, mung,* wheat and potatoes which gave Rs. 7.14, Rs. 5.74, Rs. 3.98, Rs. 3.38, Rs. 3.67 and Rs. 3.55, respectively.

Crop Rotations

Multiple cropping trials in Delhi were initiated in 1965-66. **Table 3** reveals the average yield of individual crops and also the total production individually of the twelve crop rotations in Delhi in various years, since 1967-68 to 1972-73. The average total production for various crop rotations and also of their individual crops has been worked out in the last column of the table. Most of the sequences are three crop rotations, however, production of four and two crops sequences is also included. Wheat in *rabi* and green gram (mung) in summer are invariably incorporated in most of the rotations, while Delhi farmer has a wide choice from the cafetaria of crops such as paddy, bajra, maize and arhar during the monsoon season. The total yield of crop rotations which incorporates food grains, ranges from 65.3 quintals per hectare to 117.03 quintals per hectare.

The total production does not form a comparative parameter as the production potential of individual crops is not equivalent. The average production of wheat grain is much higher than a pulse like green gram. In crop rotations the total yield is low when

Table 3: Yields of multiple cropping systems in Delhi (1967–68 to 1972–73)
(Yield of grains in quintals per hectare)

Sl. No.	Crop Rotations	Crop	1967–68	1968–69	1969–70	1970–71	1971–72	1972–73	Average
1.	Paddy-wheat-cowpea	Paddy	–	34.58	74.10	–	30.00	43.25	45.48
		Wheat	–	58.80	**	–	40.00	56.25	51.68
		Cowpea	–	7.76	8.70	–	2.77	6.75	6.50
		Total production	–	101.14	82.80	–	72.77	106.25	103.66
2.	Paddy-wheat-*mung*	Paddy	76.35	36.27	53.61	55.61	58.03	–	55.98
		Wheat	63.30	46.30	52.36	54.61	57.08	–	54.73
		Mung	7.34	7.87	5.81	6.24	4.32	–	6.32
		Total production	146.99	90.44	111.78	116.46	119.43	–	117.03
3.	Paddy-potato-*mung*	Paddy	–	–	–	–	51.62	–	51.62
		Potato	–	–	–	–	310.00	–	310.00
		Mung	–	–	–	–	5.00	–	5.00
		Total production	–	–	–	–	366.62	–	366.62
4.	*Bajra*-wheat-*mung*	*Bajra*	28.96	42.47	37.47	28.88	21.99	39.27	33.17
		Wheat	63.01	53.15	42.06	51.27	55.34	60.96	54.30
		Mung	5.11	2.91	3.00	6.15	5.32	6.71	4.87
		Total production	97.08	98.53	82.53	86.30	82.65	106.94	92.34
5.	*Bajra*-wheat-cowpea	*Bajra*	–	33.57	–	16.55	23.46	36.99	27.64
		Wheat	–	50.20	–	41.13	61.00	46.85	49.79
		Copea	–	2.77	–	6.17	4.83	11.00	6.19
		Total production	–	86.54	–	63.85	89.29	94.84	83.72
6.	*Bajra* green fodder (*Jowar/Bajra/* Maize)	*Bajra*	–	–	42.48	23.03	20.84	28.58	28.73
		Wheat	–	–	59.90	52.78	52.35	53.17	54.55
		Green fodder	–	–	185.25	144.08	179.78	225.17	183.57
		Total production	–	–	287.63	219.88	252.96	306.91	266.85
7.	*Bajra*-wheat lady finger (vegetable)	*Bajra*	–	–	–	–	–	29.64	29.64
		Wheat	–	–	–	–	–	46.31	46.31
		Lady finger	–	–	–	–	–	41.68	41.68
		Total production	–	–	–	–	–	117.63	117.63
8.	Maize-wheat-*mung*	Maize	49.42	45.67	28.14	22.96	36.20	35.00	36.23
		Wheat	54.55	54.46	36.82	56.36	63.71	63.58	54.91
		Mung	4.03	5.20	5.99	4.21	4.40	5.75	4.93
		Total production	108.00	104.33	69.97	83.51	104.31	104.33	96.07
9.	Maize-wheat-green fodder	Maize	–	–	–	27.48	24.22	18.53	23.41
		Wheat	–	–	–	44.86	63.99	55.57	54.81
		Green fodder	–	–	–	196.33	265.36	379.75	280.48
		Total production	–	–	–	268.67	353.57	453.85	358.70
10.	*Arhar*-wheat-*mung*	*Arhar*	–	–	–	–	17.90	15.87	16.88
		Wheat	–	–	–	–	46.83	40.03	43.43
		Mung	–	–	–	–	4.00	6.00	5.00
		Total production	–	–	–	–	68.73	61.90	65.31
11.	*Bajra*-potato-Wheat-maize	*Bajra*	31.06	–	–	–	–	–	31.06
		Potato	125.00	–	–	–	–	–	125.00
		Wheat	45.70	–	–	–	–	–	45.70
		Maize	27.80	–	–	–	–	–	27.80
		Total production	229.56	–	–	–	–	–	229.56
12.	*Bajra*-wheat	*Bajra*	27.66	44.67	–	23.65	23.38	24.25	28.72
		Wheat	61.33	42.23	–	45.50	48.12	43.50	48.13
		Total production	88.99	86.90	–	69.15	71.50	67.75	76.86

** Complete crop failure.
Source: National Demonstrations (1967–68, 1968–69, 1969–70, 1970–71, 1971–72, 1972–73), I.A.R.I., New Delhi.

two pulse crops are present in a three crop sequence, compared to other rotations where two cereal crops are present. It is however possible to compare the total production of rotations having similar crop sequences.

Economic Analysis of Multiple Cropping

The cost benefit analysis of the various crop rotations of Delhi is detailed in **table** 4. The economic analysis is based on the production method and prices of the specific year mentioned against the particular crop rotation. Most of the data is relating to 1972-73. In three cases, previous data has been taken as these were the latest years of such crop rotations. The return from the sale of byproducts is also included in the receipts. The highest net profit per hectare of Rs. 10,341.85 is realized from the four crop rotations of bajra-potato-wheat-maize. The second highest return of Rs. 8150.04 per hectare accrues from the three crop sequence of paddy-potato (vegetable)-mung, followed by bajra-wheat-mung and paddy-wheat-cowpea, with net returns per hectare of Rs. 6726.29 and Rs. 6214.34, respectively.

The net return per rupee invested relating to each multiple cropping pattern is also analysed. The return in every case is higher than the investment. The maximum net return per rupee invested is 2.26 from the crop se-

Table 4. Cost-benefit analysis of crop rotations.

Sl. No.	Crop Rotations	Year	Total yield ql/ha	Gross return Rs/ha	Total cost Rs/ha	Net return per ha (Rs)	Net return per rupee invested per ha
1.	Paddy-wheat-cowpea	1972–73	106.25	8968.50	2754.16	6214.34	2.26
2.	Paddy-wheat-*mung*	1971–72	119.43	9069.43	3319.88	5749.55	1.73
3.	Paddy-potato-*mung*	1971–72	366.62	13123.15	4973.11	8150.04	1.64
4.	*Bajra*-wheat-*mung*	1972–73	106.94	9991.89	3265.60	6726.29	2.06
5.	*Bajra*-wheat-cowpea	1972–73	94.84	8533.10	2910.87	5622.23	1.93
6.	*Bajra*-wheat-Green fodder	1972–73	306.92	8260.25	2817.61	5442.64	1.93
7.	*Bajra*-wheat-lady finger	1972–73	117.63	9065.63	3699.69	5365.57	1.45
8.	Maize-wheat-*mung*	1972–73	104.33	9287.08	3264.63	6022.45	1.84
9.	Maize-wheat-green fodder	1972–73	453.85	8577.67	3269.20	5308.47	1.62
10.	*Arhar*-wheat-*mung*	1972–73	61.90	6786.30	2982.72	3803.58	1.28
11.	*Bajra*-potato-wheat-maize	1967–68	229.56	15518.34	5176.49	10341.85	2.00
12.	Bajra-wheat	1972–73	67.75	5712.25	2406.19	3306.06	1.37

Source: National Demonstration (1967–68, 1971–72 and 1972–73), I.A.R.I., New Delhi.

quence of paddy-wheat-cowpea. This rotation is followed by *bajra*-wheat-*mung* and *bajra*-potato-wheat-maize with benefit cost (B/C) values of 2.06 and 2.00, respectively. The crop seqnences are commonly practised on irrigated fields in the area. The four crop sequences are possible, however, poses practical problems in actual practice. A farmer may choose a three crop sequence from the cafeteria of crop suited to his circumstances.

Cropping patterns for Problem Soils

A substantial portion of culturable area of Delhi has problems of salinity and alkalinity. With a view to solve this problem and to evaluate economic returns, special demonstrations have been organized since 1970-71. Following is the sequence of events and the results of the special demonstrations during the previous three years.

In the first year, during 1970-71 monsoon season, leaching was done with 2.5 tonnes of gypsum per hectare. Barley variety 'Ratna' was raised in the following winter season. In summer, green manuring crop of *dhanicha* was buried with 2.5 tonnes of gypsum per hectare.

In 1971-72 the rotation followed was paddy, IR-8 variety with 2.5 tonnes per hectare of gypsum during *kharif*, wheat (Kalyan sona) in *rabi* and *dhanchia (Sesvania Aculeata)* as green manuring is summer. In 1972-73 wheat (Sonalika) was followed by *dhaincha* as green manuring crop. This technology of multiple cropping and soil amendments reduced the pH value from 9.7 to 8.5.

The food grain yield of the first year in 1970-71 was 12.00 quintals per hectare of barley, which increased in 1971-72 to 69.10 quintals per hectare. The investment per hectare during 1970-71, 1971-72 and 1972-73 was Rs. 1072.91, Rs. 2958.35 and Rs. 2040.00, respectively. The net return per hectare during the respective years was Rs. -208.91. (loss), Rs. 2896.85 and Rs. 3744.99. With the trend of the results, economic benefits are likely to improve with coming years. Thus, it is possible to get a remunerative return even from problem soil by employing the desired technology.

The results of multiple cropping demonstrations opens up a new vista for the farmers of Delhi. It is evident that four and three crop sequences are possible and economically sound, and more beneficial as compared to a two crop sequence, which has been commonly practised in the area. These is ample scope of improving yields and obtains higher economic returns by appropriately regulating and exploiting the required inputs during the growth cycle of crops. The adoption of multiple cropping is inevitable under the current trend of population growth and increasing demand of food and fibre. The national planning has to be based on the input and infrastructure requirements of multiple cropping. Multiple cropping is a way out to increasing the living standard of farmers who are fully dependent on the income from the small holdings in India. The present widespread adoption and popularity of multiple cropping is dependent upon the availability of healthy and pure seeds and input requirements, specially the fertilizer. The policies of popularising multiple cropping will have to be carefully examined and judged in the context of the requirements of inputs, infrastructure and the impact on the gross national produce with the available resources. ■ ■

Multiple-Cropping and Mechanization

Performance Data Needed for Selection and Management of Machinery

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Introduction

During a recent study on farm mechanization in Asia, the authors became aware of a serious deficiency with regard to available information for purposes of farm planning. This deficiency is the inability to compare various types of agricultural implements designed to accomplish a specific task.

Within a country, if a wide variety of agricultural implements is available, farmers through trial and experience will over time determine the optimal combination of agricultural machinery. However, when a government is seeking to introduce agricultural machinery for the benefit of the country, it is imperative that a careful analysis of alternatives be made to avoid years of trial and error under actual operating conditions. When an individual farmer makes a poor choice, he and his family may suffer the consequences. However, his friends and neighbors probably receive a benefit through learning that the particular machine or equipment set was a poor choice which they should avoid.

On the other hand, when a decision is made that determines the type of equipment that will be available within a country, a poor choice adversely affects a large segment of the population both rural and urban. Consequently, the greatest care must be taken in order to develop meaningful comparisons among the various types of equipment available internationally.

For purposes of effective planning it is necessary to determine:

1. The performance of implements being considered.
2. Operating costs under normal conditions (e.g., fuel, oil, grease, repairs, etc.).
3. Operational life, depreciation schedules, etc.
4. Cost of production (if the equipment is to be produced domestically) or cost of importation. (Even when machinery is domestically produced it may be necessary to import certain components.)

At this time, the authors want to focus attention on the first of these since it presents the greatest single obstacle to national planning to achieve farm mechanization in Asia.

The proper selection and management of mechanical power and machinery will increase the

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capacity to produce more crops with less drudgery and greater effectiveness and efficiency. A farm may be compared with a factory that is producing several items for market and the management goal is to maximize profits. The machines which are used on the farm are merely tools of production and have costs that subtract form gross income. The performance of a machine is profitable only when the economic returns from the products exceed the production costs.

Economic management of power and machinery is usually the most significant factor contributing to farm profits since machinery costs may comprise the single largest item of annual farm costs. In general if the capacity of a machine or power unit is too low, operating costs will be excessive and untimely operations may result in lower profits due to a decrease in quantity and quality of crops. If capacity is too great, the higher fixed costs, which are the result of limited use, make the machine less profitable to use and in some cases even unprofitable. The optimum size machine will occur between these two extremes. Therefore, it is necessary to have quantitative measures of the machine performance capacities to aid in selection. Usually planning agencies cannot test machines before purchasing and must depend on the manufacturer's data or upon results obtained by testing agencies. Therefore, it is extremely important that specific comprehensible terminology be used in describing and reporting the performance capabilities and specifications of power units and machines by manufacturers, researchers and testing agencies.

The overall economic performance of a farm utilizing machinery may be expressed in terms of cost per unit of output. The input data necessary to determine the economic performance involve machine capacities, power requirements, and costs.

Machine Performance

The performance of an agricultural machine is usually expressed in terms of time rate (some physical quantity accomplished per unit of time). Rate is an important performance criterion because of the timely operations (ability to perform an activity at such a time that quality and quantity of product are optimized) required in agricultural production with its sensitivity to season and weather. The term machine capacity is used to express the rate of performance. The definitions specified in the ASAE (American Society of Agricultural Engineers) (1) Standard on Uniform Terminology for Agricultural Machinery Management are used in this paper.

The theoretical field capacity of a machine is the rate of performance if a machine performs its function 100 percent of the time at the rated operating speed using 100 percent of its rated width. The effective field capacity is the actual rate of performance of land or crop processed in a given time from the start of a functional activity to the time the functional activity for the field is completed. Field efficiency is the ratio of effective field capacity to theoretical field capacity expressed in percent.

Although field capacity is usually expressed as area per time, the definitions are sufficiently broad to include material processed per unit of time. The quantity of material processed may be expressed as the volume or weight of material harvested (i.e., liters per hour or kilograms per hour) or the weight of material handled (kilograms or metric tons per hour). Due to the differences in crop conditions and yields at time of harvest, a machine may have a low area per hour capacity and a high volume or weight per hour capacity in one field and both capacities be high in another field. Therefore, the volume or weight per hour capacity would be preferred in describing harvesting machine performance. However, to be more precise the moisture content of the material harvested should be included for the capacities reported.

Theoretical field capacities are normally not achieved because it is not possible to operate continuously nor at the rated width of the machine. Therefore, the effective field capacity will be lower than the theoretical field capacity.

The theoretical field capacity is a function of operating width and speed of travel, which are constant for a given set of conditions for a functional activity. The effective field capacity depends upon the percentage of the operating width actually used, the average speed of travel while performing the functional operation and the amount of field time lost that was not devoted to the functional activity. With implements such as harrows, planters, cultivators, mowers and combines, it is practically impossible to utilize the full width without overlap. The amount of overlap is largely a function of speed, field conditions and operator skill. Under some conditions the yield of a crop or the condition at time of harvest (e.g., sever lodging of grain) may prevent operation of the machine at full width even at minimum forward speed obtainable with the prime mover. The average forward speed depends upon the nature of the functional activity, the condition of the field and/or crop and the amount of power available.

Lost field time may be due to machine adjustments, maintenance (lubrication, refueling, belt tightening, etc.), repair (replacement of inoperative parts), adding seed or fertilizer, unloading harvested products, and turning at ends of field. Time for setting up or daily servicing of equipment, travel to and from field, and major breakdowns are not included in time charged to a functional activity.

For a given functional activity with known or measured conditions, the effective field capacities may be calculated. The relationship for capacity in hectares per hours is given by Equation 1.

$$CA = \frac{SWE}{10^6} \qquad (1)$$

where:

CA = capacity in hectares per hour
W = width of machine in millimeters
S = speed of machine in kilometers per hour
E = field efficiency in percent

The amount of material processed or harvested may be determined by Equation2.

$$CM = \frac{MSWE}{10^6} \qquad (2)$$

where

CM = kilograms per hours
when
M = kilograms per hectare
or
CM = kiloliters per hour
when
M = kiloliters per hectare

Field efficiencies are not constant values for specific machines and may vary widely. The factors affecting the values of reported field efficiencies (1,2) include: pattern of field operation; shape of field; size of field, theoretical capacity for the functional activity; crop yield, if harvesting activity; and conditions of crop, including moisture content. A detailed discussion of the influence of these factors is presented by Hunt (3). It is not sufficient to report field efficiencies without a description of conditions under which they are obtained.

Since a planning agency may have difficulty in applying reported field efficiencies directly to conditions within a specific country, more emphasis should be placed upon reporting theoretical field capacities. Instead of reporting area per hour or quantity of material processed per hour, the operating speed and, if harvesting, the yield per hectare as well as moisture content of product should be given. Values for soil preparation equipment should include speed, depth and width of implement, type and condition of soil. Data could be obtained under actual field conditions using a straight uninterrupted length of at least 100 meters. These data could be called empirical field capacities. The main objective as indicated earlier is to have quantitative measures of machine performance which are meanigful.

Power Unit Performance

Good machinery management also involves the selection and economic operation of prime movers and power units. To determine the optimum size of power unit, the power requirements of the machines at their respective empirical field capacities should be known. For economy, no more power than is necessary should be available to perform a given functional activity. Inefficient use of power, having too much or too little, can greatly increase the cost of the activity.

To determine the power used by a machine, three things must be known: the force, the distance through which the force acts, and the time the force is acting. Power is the rate of doing work; while work is defined as the application of a force through a distance. The term horsepower is commonly used to express the performance of prime movers and the power requirements of field machinery.

Power is utilized on the farm for tractive and stationary work. Stationary work is usually accomplished by means of a belt, gears, or power-take-off and includes such tasks as water pumping, threshing, forage cutting and spraying. Examples of tractive work are plowing and land preparation, planting and sedding, harvesting and hauling. The primary source of power in developing countries is the internal combustion engine. The engines used for agricultural operations are primarily spark ignition and compression ignition engines. The spark ignition engines, desgined for fuel such as gasoline and kerosene, utilize an electric spark for fuel combustion while the compression ignition engines, designed for such fuel as diesel oil, depend upon compression energy to ignite the fuel mixture.

The power output of an internal combustion engine is a function of the mean effective pressure on the piston head created by the combustion process, and the engine speed during the power stroke and is called indicated horsepower. The most frequently measured power is brake horsepower, which is the power delivered by the engine crankshaft. The difference between the indicated horsepower and the brake horsepower of an engine is defined as friction horsepower. It is the power required to run the engine at any given speed without production of useful work and represents the friction and pumping losses of an engine.

Since the brake horsepower involves rotary motion the term torque is used in determining the force developed acting through a distance. Torque is the twisting or turning moment, visualized as the work per unit of rotation. It is a measure of the ability of an engine to do work, while power is a measure of the rate at which the work is done. For example the torque developed determines whether an engine can drive a forage chopper processing a

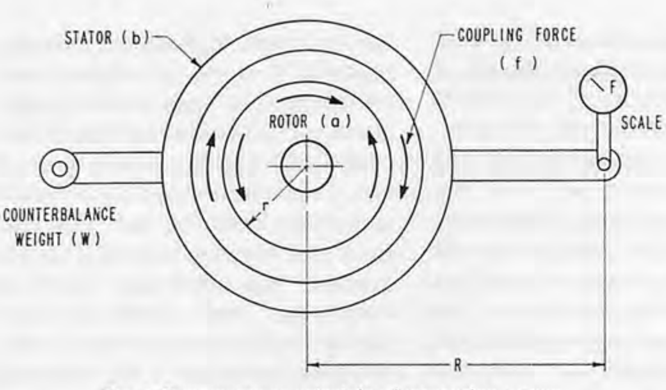

Fig. 1. Dynamometer principle of measuring torque.

given crop material, whereas the power determines how quickly the material can be put through the chopper.

A dynamometer is used to determine the torque developed by an engine. Although there are many types of dynamometers, all operate on the principle illustrated in **Figure 1.** The Rotor a, driven by the engine to be tested, is coupled (electrically, magnetically, hydraulically or by dry friction) to the Stator b. In one revolution of the shaft, the peripheral surface of the rotor moves through a distance $2\pi r$ against the coupling force f. Therefore, the work per revolution is

$$\text{Work} = 2\pi rf \qquad (3)$$

The external moment, which is the product of the reading F of the scale and the arm Requal the turning moment, which is $r \times f$. Therefore, equation 3 may be written as

$$\text{Work} = 2\pi RF \qquad (4)$$

When the engine is turning at N rpm the work per minute becomes

$$\text{Work per minute} = 2\pi PRN \qquad (5)$$

which can be expressed as horsepower.

$$hp = \frac{2\pi(RF)N}{33,000} \qquad (6)$$

The SAE (Society of Automotive Engineers) and the ICEI (Internal Combustion Engine Institute) have established standards for measuring performance characteristics of internal combustion engines. Test results include power and torque curves as a function of engine speed (**Figure 2**). Manufacturers use terms such as maximum, net, intermittent and continuous horsepower to describe performance of an engine. However, these terms may be of limited value unless additional test conditions are presented.

Maximum horsepower is the horsepower measured at the engine flywheel without any of the power consuming accessories, such as the exhaust system, cooling system generator and air cleaner. Maximum horsepower is obtained by determining the point on the power curve (**Figure 2**) where an increase in speed results in no increase in power. Although an engine is capable of running faster than the speed at which maximum horsepower is developed, the decrease in power is due to a lower volumetric efficiency and higher internal friction.

Maximum horsepower is normally used in the automotive industry, since automotive engines are not designed to operate continuously at maximum power. However, the development of maximum power for any length of time will greatly shorten the life of an engine. Since agricultural power units and prime movers are expected to perform with accessories at a given power level for long periods of time, maximum horsepower would be of little benefit.

Net horsepower is measured the same way as maximum horsepower but with the accessories mounted on the engine. In general the net power and torque curves are utilized for rating industrial and agricultural power units and prime movers. The rated operating speed is usually several hundred rpm (200-800) higher than the peak torque speed. The rated operating speed being higher than the peak torque makes it possible to take advantage of the torque reserve. When an engine is loaded with an unexpected increase in torque due to an overload, the operating speed has a tendency to drop immediately. As the speed decreases toward the peak torque speed, torque increases and may enable the engine to overcome the overload.

Intermittent horsepower ratings are usually stated as 90 percent of the maximum net rating and continuous ratings are approximately 80 percent of the maximum rating.

In addition to the brake horsepower ratings, agricultural power units and prime movers may have belt and power-take-off ratings. Due to the additional mechanical components needed to transmit the power, the power-take-off and belt performances will be lower than the brake horsepower rating. The ASAE Agricultural Tractor Test Code (1), Nebraska Tractor Tests (4) and the O.E.E.-C. Standard Code and Test Bulletin for Agricultural Tractors (5) outline procedures for determining the PTO and belt performances.

For prime movers, the power which is developed at the hitch

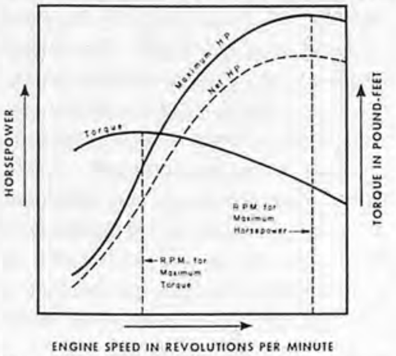

Fig. 2. Relationship of horsepower, speed and torque for internal combustion engines.

point or drawbar and which is available for pulling a load is an important performance criterion. Drawbar pull is seriously influenced by the soil or test track conditions and also by the gear ratio and the ballast being carried. The ASAE Tractor Test Code, Nebraska Tractor Test Code and O.E.E.C. Standard Code outline procedures for testing and reporting drawbar performance.

In addition to the power performance of the power units and prime movers, the fuel consumption rates for rated and part-load conditions should be available. The data can be used as an efficiency indicator in determing operating costs.

Fixed and Operating Costs

The total cost of performing a functional activity includes charges for the machine, for the power utilized, and for labor. Machine costs include depreciation, interest on investment, taxes, insurance, housing repairs, and maintenance, lubrication And fuel and oil. The first five items are related to machine ownership and are known as fixed costs. Expenses for items such as repairs, maintenance, lubrication, fuel and oil, and labor result from actual machine operation and are known as operating costs.

Depreciation is the reduction in value of a machine caused by such an enterprise changing and the existing machine's capacity not being appropriate for the new situation. Among the various systems employed for calculating depreciation are the straight-line, constant-percentage, estimated-value, and compound-interest methods. For calculating the cost of operation, the straight-line method is the most practical and most common. It is the simplest method and gives a constant annual charge for depreciation during the life of the machine. A salage value equal to 10 percent of the initial cost is normally assumed at the end of the life expectancy of a piece of machinery. The constant-percentage and estimated-value methods depreciate the value of the machine more rapidly than the straight-line method in the early years of the machine's life and less rapidly in later years.

The service life of a machine is needed to estimate depreciation. Service life depends on the feasibility of repairing or replacing worn parts. In general the service life is the length of time from purchase of machine to that time when it is more economical to replace with another machine than to continue using the first machine. A common method for determing the probable service life is to conduct a survey among a large number of farmers, obtaining from each owner the present age of the equipment and his estimate of the expected future life.

Interest on the investment in a farm machine is included because the money used to buy a machine cannot be used for other productive enterprises. The amount invested is greater during the early part of the service life since an amount is written off each year as depreciation. Interest charges may be calculated so that the results will be constant or so there will be equal yearly charge throughout the life of the machine.

When the straight-line method of depreciation is used, an annual interest charge on the average investment in the machine over its full life s normally used. The average investment is equal to one-half of the sum of the first cost and the salvage value. The annual interest charge is the product of the interest rate and the average investment.

Taxes will depend upon the local situation and the method of assessment.

While it is not a universal practice to insure farm machinery against loss by fire or windstorm, in most cases the insurance charge is justifiable. The rates for farm machinery are variable but the annual charge should not exceed 0.5 percent of the initial cost.

Numerous attempts have been made to obtain evidence of the value of housing for farm machinery. Most have failed to find such evidence; however, some observations have revealed that, although monetary savings are not apparent, there are indeterminate values such as better management, better appearance of the machinery, and ease of making repairs during a slack or inclement season, and have thereby justified the expense of housing. The annual charge for housing should not exceed 1.5 percent of the original purchase price.

Due to wear, part failures and accidents, expenditures are necessary to keep a machine in operating condition. The cost of repair (labor and parts) is an important cost as it may determine when to replace a machine. Mainteance costs (adjusting for wear and lubricatiog) and the cost of labor required for maintenance should be included as repair costs. Published surveys of machinery cost records have permitted estimates (1,2) of repair and mainteance costs. The amount required for repairs and maintenance is one indication of the management level of an individual manager.

The quantity of fuel required for a specific functional activity depends upon the size of engine and the type of fuel it uses. The fuel consumption rates may be obtained from the power test data discussed earlier. If an annual average fuel requirement is desired, it can be determined from the varying load test results since the power unit will not be operated at continuous rating at all times.

The costs for oil, grease and oil filter can be determined from instructions in the operator's manual. A common practice is to assume that the costs are some percentage of the fuel cost and a value commonly used is 15 percent.

The cost of labor varies. For owner-operators, labor costs should be determined from alternative opportunities for the owner's time. For a hired operator, a constant hourly rate is appropriate. In on instance should the charge be less than a typical community labor rate.

The best procedure for obtaining data on an existing machine is to keep accurate records on operating costs. While the operating costs cannot be directly transferred to a newer machine with improved functional capacity and performance, the data can be helpful in arriving at values to use in evaluating and comparing commercial machines available.

Summary and Conclusions

Although it is possible to devise means of evaluating alternative pieces of agricultural equipment, most planning agencies do not have the time or the resources to evaluate specific types of farm equipment. Within the United States of America the Nebraska Tests provide a continuing flow of information concerning performance of selected types of farm machinery performing under standardized conditions. However, the equipment tested is of limited use given the current land tenure and farm size in most of Asia today.

Even though the Nebraska Tests are not themselves applicable, perhaps the concept is. Management decisions resultIng in optimum labor and machinery costs must be based on as reliable data as possible. The utilization of uniform terminology in describing the performance capabilities and specifications of power units and machines will contribute greatly toward sound machinery selection as efforts to mechanize Asian agriculture continue. However, such a uniformity of terminology could best be achieved through the creation of an agency whose sole function would be to test farm equipment under standardized conditions. Such information would provide truly meaningful informatIon for national planners.

Since this information is needed by nearly all of the countries of Asia and perhaps most of the countries of Africa and South America, it would seem reasonable that an international structure and funding should be sought. Manufacturers of farm equipment should be able to used the results to seek means of improving their product.

The ability to establish standardized tests that yield data for planning purposes has been demonstrated by the history of the Nebraska Tests. The benefits of international cooperation on agricultural research have been demonstrated by the performance of IRRI (International Rice Research Institute). It only remains for the agricultural leaders of Asia to take the lead in establishing such a facility.

REFERENCES

1. *1972 Agricultural Engineers Yearbook.* American Society of Agricultural Engineers, St. Joseph, Michigan.
2. *Asian Productivity Organization Project Report. SYP*/111/67, Volume 1, 1967.
3. Hunt, Donnell. *Farm Power and Machinery Management, Laboratory Manual and Workbook.* Iowa State University Press, Ames, Iowa, 5th Edition, 1968.
4. The Nebraska Tractor Tests. The Agricultural Experiment Station, University of Nebraska, Lincoln, Nebraska, January 1, 1972.
5. O.E.E.C. Standard Code and Test Bulletin for Agricultural Tractors. The European Productivity Agency, Organization for European Economic Cooperation, 3 rue Andre-Pascal, Paris-16.
6. Obert, Edward F. *Internal Combustion Engines.* Internal Textbook Company, Scranton, Pennsylvania, 3rd Edition, 1968.

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Farm Size, Mechanization and Labour Employment

—Some Dynamic Issues—

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It is seemingly clear that the labor employment per unit of land is inversely associated with the farm size and as such the policies aiming at social justice through reduction in the ceiling limit of the farm holdings and redistribution of land amongst the small farmers and landless labourers receive a strong favouritism that it would increase the sphere of self employment (7). The creation of employment through increasing the number of small holdings, in the above analogy, is more in the static sense than in the dynamic one and merely scraps the surface for it ignores the other aspects behind this creation of employment. Land and labour are just the two resources, before labour gets work, many other resources, grouped as capital, and capital is not simply finance where institutions can come to rescue, are needed. Where from will these resources come? Are the small farmers not already capital starved? Also, assuming that once it is done and completed, where from the future potential would come?

The issue of labour employment in relation to farm size and mechanization has been strongly debated in the recent past. In some studies, the intensive use of labor, it being considered as an abundant resource, has been recommended and the introduction of mechanical power, especially of tractors, has been considered not advisable (2, 16, 17, 18). The addition of one new mechanical technology after another has been shown to displace labour through simple yardstick approach (1, 11). But, whereas any machine performing a certain operation does decrease labour requirement for that particular operation only, the aggregate impact of the machine on labour requirement is not a simple addition or subtraction process; rather it depends upon how those different operations from an integral part of the complete machinery system.

There are many other studies which conclude the other way, that the mechanized farms employ more labour than the non-mechanized ones (3, 4, 9, 13). But these studies are more of a static nature and either have mixed the farm size effect with mechanization effect (9) or compare only the matching farm size groups with limited variation (3, 13). The physical production possibility curve or isoquant showing the interaction of mechanical power and labour employment has been shown to shift upward with the improved technology and the increase in labour employment (and

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labour productivity) will come only by using more machine power than is being used in the traditional technology (4). But in this study, too, the farm size effect was not considered. Thus, the employment of labour over the entire range of farm size on differently mechanized farms has not been compared so far, nor was the analysis extended to over time.

The empirical evidence, thus, is still inadequate for setting operational guidelines towards the employment creation objective on the farms. This needs a very careful examination of (i) where does the potential exist? What are the conditions and situations needed to exploit the potential? (iii) where these conditions can be economically taken up (cost benefit ratio of investments)? and (v) where and how this potential can be further enhanced?

The Process

The issue put forward in this article is that the existing agrarian structure (the existing level of ceiling and the size distribution of holdings) is more favourable for creating employment in the long run and that the system itself has adjusted overtime in the best interests of economic efficiency (14). The lumpy capital investments are made on large farms where they are profitable. These investments such as irrigation structures, tractors and their associates and second complements (machines which can be had only after having these machines for they work with the energy inputs such as threshers, crushers, shellers, etc.) help to increase the employment on large farms by enabling them to increase the intensity of operations and cropping intensity, by increasing the yield through timeliness and scientific performance of the operations and thus increasing labour requirements for other operations positively associated with yield, etc. (4, 10). These lumpy investments remain surplus on large farms and are hired out to the small farmers who also benefit therefrom and the labour utilization on these farms increases through the same process.

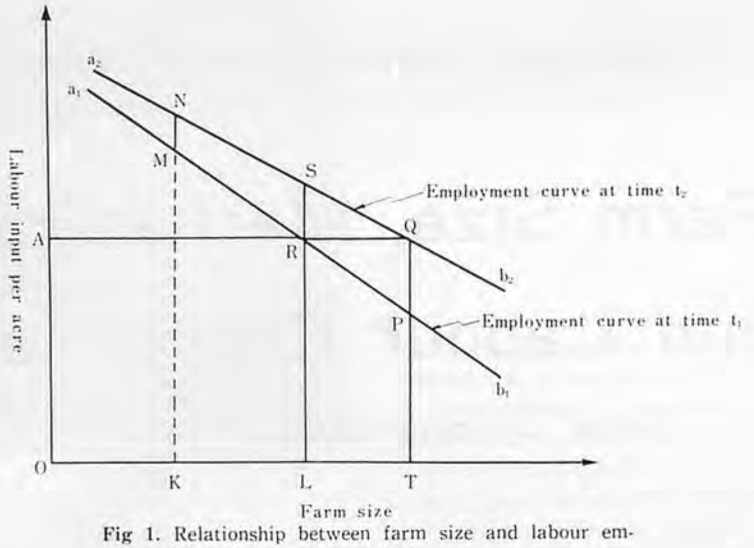

Fig 1. Relationship between farm size and labour employment per acre over time

Diagrammatically the process is explained in **Fig. 1** which shows that at time t_1 labour employment per acre is governed by curve (a_1 b_1). To increase employment to the level of OA per acre, there are two alternatives. One is that the farm size be reduced to OL but then no more would turn out. There is doubt even if this comes upto expectations: The other alternative is that let the farm size distribution be as it is, introduce improvements in the form of lumpy capital investments to gear up the process of creating labor employment which will shift the employment curve itself from a_1 b_1 to a_2 b_2. Thus overtime t_2, labour employment upto OA per acre may be achieved on farm sizes greater than OL upto OT. There will also be increase in employment on small farms, say of size OK, which is MN, is because of the increase in employment on large farms, say of size OT, which is PQ. Thus, overtime, this process helps to increase employment through creating employment potential and not simply through tapping the existing potential.

Empirical Evidence

The time series data for a sufficiently long interval, to prove the foreset, hypothesis is hardly available. However, a critical examination of the cross-sectional data of different categories of farms classified according to varying levels of mechanization would also show the particular direction (s) which labour employment (input) per acre assumes under the changing circumstances (7).

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The data from two different sources were used for this study:

I Farm Management Study:

The cost accounting date from the Farm Management studies in Ferozepur District (Punjab) for 1968-69 and 1969-70 (5). The observations in Zone- I and II only were considered because the tubewell irrigation was in common use in this area and the farms could be considered as more homogeneous and representative for larger area of the state. The zone III was mostly canal irrigated, with larger unirrigated area and mechanization of different levels was not very wide.* Hence, this zone not included in this investigation.

The farms in this study were classified into bullock operated tubewell irrigated and tractor operated tubewell irrigated ones, thus depicting a distinct change in the source of draft power from bullocks to tractor.

II **Punjab Study:**

The survey data for different type of farming areas of the central plains of Punjab for 1968-69 (12). The following farm categories were developed from the data of this study:

1. Non-bet type of farming area :
    - A. Bullock operated-persian wheel irrigated.
    - B. Bullock operated-persian wheel plus canal irrigated.
    - C. Bullock operated-tubewell irrigated.
    - D. Bullock operated-tubewell plus canal irrigated.
    - E. Tractor operated-tubewell irrigated.
2. Bet type of farming area :
    - F. Bullock operated-persian wheel irrigated.
    - G. Bullock operated-tubewell irrigated.
    - H. Tractor operated-tubewell irrigated.

These farm classifications depicted two distinct changes in the level of mechanization, viz., the change in the source of irrigation from passion wheel/plus canal to tubewell/plus canal and change in the source of draft power from bullocks to tractors.

Total Labour Input

The average labour input per acre, the farm size, simple correlation between these variables and the linear regression** of labour input per acre on farm size ($Y=a+bX$) are given in **Table** 1 and 2.

It will be seen from **Table 1** and 2 that all the correlation coefficients were negative and signi-

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* There were only 7 and 7 tractor operated farms out of the sample of 70 farms in Zone III during 1968-69 and 1969-70 respectively as compared to 21 and 28 out of sample of 80 farms in Zone I and II during these years respectively.

** The log-libear regression was also tried in case of Punjab Study (Appendix I), but it did not show any significant improvement in R^2 nor does it deviate from the results explained henceforth.

Table 1. Linear relationship between labour input per acre and farm size on farms with different levels of mechanization, Ferozepur, Punjab, 1968–69 and 1969–70.

S. No.	Farm classification with source of		N	Av. Labour input per acre in man days (Y)	Av. farm size in acres (X)	Simple correlation	Linear regression of labour input per acre on farm size Y = a + bX
	Draft power	Irrigation					
I. 1968–69							
1.	Bullock	Tubewell	44	36.49	23.62	–0.5231*	Y = 49.5306 –0.5521X
2.	Tractor	Tubewell	21	37.47	41.00	–0.5011**	Y = 53.8331 –0.3991X
II. 1969–70							
3.	Bullock	Tubewell	40	37.89	21.10	–0.5282*	Y = 52.7507 –0.7043X
4.	Tractor	Tubewell	28	38.53	41.48	–0.3317	Y = 47.9543 –0.2272X
5.	Tractor	Tubewell	21	35.04	44.62	–0.4626**	Y = 46.7572 –0.2626X

Note: (a) One village was very distinct from others. There were larger number of fragments of each holding, persian wheels were also used as source of irrigation and majority of the farmers (9 out of 10) did wheat threshing with bullocks. These operations being too much labour intensive, put these farms on a different plateau of labour employment. Hence this village was excluded from this study.

(b) For 1969–70, from tractor operated farms, in regression (5), 7 exceptional observations were deleted. These comprised of 3 farms which purchased tractor late in 1969–70 and hence tractor effect was not completely realized; 2 very small farms of 6.63 hectares each where tractor was very surplus; and 2 farms belonged to the same village which was excluded for reasons in (a) above.

(c) In all analysis, regression 5 in stead of regression (4) was considered, the correlation being significant in the former regression only.

* – Significant at 1 per cent level   ** – Significant at 5 per cent level

Table 2. Linear relationship between labour input per acre and farm size on different farms with varying levels of mechanization, Punjab, 1968–69.

S. No.	Farm Classification with Source of		N	Average labour input per per acre in man days (Y)	Av. farm size in acres (X)	Simple correlation	Linear regression of labour input per acre on farm size Y = a + bX
	Draft power	Irrigation					
I. Non-bet type of farming area							
A.	Bullock	Persian wheel	40	72.29	7.22	–0.5127**	Y=108.0449–4.9522 X
B.	Bullock	Persian wheel plus canal	40	65.99	9.43	–0.4154**	Y= 86.4220–2.1667 X
C.	Bullock	Tubewell	40	54.86	12.07	– .4383**	Y= 71.5202–1.3803 X
D.	Bullock	Tubewell plus canal	40	57.70	14.36	– .6457**	Y= 80.5109–1.5885 X
E.	Tractor	Tubewell	28	48.49	35.01	– .3723*	Y= 58.3313–0.2811 X
II. Bet type of farming area							
F.	Bullock	Persian wheel	40	57.70	10.50	– .3803*	Y=72.8841–1.4461 X
G.	Bullock	Tubewell	40	44.65	19.16	– .3827*	Y=52.3562–0.4022 X
H.	Tractor	Tubewell	27	41.46	40.21	– .6355**	Y=53.2978–0.2944 X

* Significant at 0.05 probability level   ** Significant at 0.01 probability level

ficant at a probability level of greater than 0.05. The estimated equations were tried for the equality of the corresponding coefficients in different pairs of equations representing a change in the level of mechanization trough a test of the equality of the regression equations (10). The results of this test, as presented in Appendix II, showed that the coefficients of any two different levels of mechanized farms which were compared, were significantly different from each other, at probability level of 0.05 in all cases except one in the Punjab Study which was bullock operated persian wheel plus canal irrigated and bullock operated tubewell plus canal irrigated farms in the non-bet type of farming area.

The regression coefficient 'b' in the linear regression, which indicates the slope of the regression line showed very consistent pattern. In the Ferozepur study, it was -0.5521 on bullock operated farms as compared to -0.3991 on tractor operated farms during 1968-69. During 1969-70, the 'b' value was -0.7043 and -0.2626 on bullock operated and tractor operated farms respectively. Thus with the increase in the level of mechanization, the slope of the employment curve with respect to farm size declined.

The results of the Punjab Study also supported the same conclusion. The slope of the regression line was −4.9522 on bullock operated persian wheel irrigated farm which decreased to −1.3803 when the source of irrigation was changed to tubewell in the non-bet type of farming area. A further change in the regression coefficient to −0.2811 was observed when the source of draft power was changed from bullocks to tractor in the same type of farming area. Similarly, the regression coefficient on bullock operated-persian wheel plus canal irrigated, bullock operated-tubewell plus canal irrigated and tractor operated-tubewell (plus canal)* irrigated farms were −2.1667, −1.5885 and −0.2811 respectively, again, showing a consistent increase with the increase in mechanization in the non-bet type of farming area. In the bet type of farming area, also, the trend was the same. The regression coefficient changed from −1.4461 to −0.4022 with the improvement in irrigation and from −0.4022 to −0.2944 with the improvement in draft power through mechanization.

The value of pure constant intercept 'a' in the regression $Y=a+b\ X$ also has some significance because it shows the level at which the (employment) curve starts.** For the Ferozepur study, it was higher on the tractor operated farms than on the bullock operated ones during 1968-69 thus showing than the labour employment curve with respect to farm size for tractor operated farms is placed above (higher than) the one for the bullock operated farms. During 1969-70, there was, however, the opposite trend; 7 bullock operated farms shifted to tractor cultivation and the average farm size also changed. For the Punjab study, too, the value of 'a' decreased with the increase in the level of mechanization, except for tractor operated tubewell irrigated farms in the bet type of farming area. But here the more relevant question is to examine the trend line within the observed range of farm size on different type of farm situations and if the average labour input per acre were

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* The total number of observations for tractor operated farms were 28 only in the non-bet area in the selected villages for the year of survey which were not further separated into pure tubewell and tubewell plus canal irrigated farms to save the degrees of freedom. In the bet area, canal was a rare source of irrigation and hence canal irrigated categories could not be developed (12).

** The actual regression lines plotted on a graph are explained in a later section.

Table 3. The range of farm size and labour input per acre at minimum and maximum farm size on different farms situation in Punjab.

Sr. No.	Farm Classification with source of		Farm size range (acres)		Labour input per acre at farm size (man days)	
	Draft power	Irrigation	Minimum	Maximum	Minimum	Maximum
	Farm Management study, Ferozeour:					
I.	1968–69					
1.	Bullock	Tubewell	6.25	52.50	46.08	20.54
2.	Tractor	Tubewell	16.05	83.90	47.43	20.35
II.	1969–70					
3.	Bullock	Tubewell	6.50	47.50	48.17	19.30
4.	Tractor	Tubewell	24.12	99.35	40.42	20.67
	Punjab Study:					
I.	Non-bet type of farming area:					
A.	Bullock	Persian wheel	4	13	88.24	43.67
B.	Bullock	Persian wheel plus canal	4	14	77.76	56.09
C.	Bullock	Tubewell	6	24	63.24	38.39
D.	Bullock	Tubewell plus canal	6	28	70.98	36.03
E.	Tractor	Tubewell	20	50	52.71	44.28
II.	Bet type of farming area:					
F.	Bullock	Persian wheel	5	16	65.65	49.75
G.	Bullock	Tubewell	7	30	49.54	40.29
H.	Tractor	Tubewell	20	50	47.41	38.58

higher on farms operated at lower level of mechanization, at which level of farm size it becomes equal to that on higher level of mechanization operated farms through relatively lower declining slope of labour input on letter type of farms. The range of farm size on different types of farm situations and the labour input per acre at the minimum and maximum farm sizes are given in **Table 3**. The farm size beyond which labour input per acre is greater on farms with higher level of mechanization is given in **Table 4**.

In the Ferozepur study, it was found that the labour employment per acre on the tractor operated farms was higher than that on the bullock operated farms over the entire farm size range during 1968-69. During 1969-70, the labour employment per acre becomes equal on bullock operated and tractor operated farms at farm size of 13.57 acres beyond which it became higher on tractor operated farms.

The result of the Punjab study showed that when the source of frrigation was improved from persian wheel to tubewell, the labour input would be higher on tubewell irrigated farms of greater than 10.23 and 10.22 acres in case of no canal and canal as supplementary source of irrigation respectively in the non-bet type of farming area. Again, when the bullocks were replaced by tractor, the labour input per acre on tractor operated farms would be higher than on bullock operated ones on farms of more than 12.00 and 16.96 acres without canal and with canal as supplementary source of irrigation respectively in the non-bet type of farming area.

In the bet type of farming area, however, the farm size beyond which labour input per acre was higher on tubewell irrigated farms than on persian wheel irrigated ones was large at 9.66 acres. But the comparison of bullock operated and tractor operated farms showed that labour input per acre would be greater on all the farm sizes operated with tractor, because the pure constant intercept 'a' in case of tractor operated farms was higher at 53.2978 as compared to 52.3562 on bullock operated farms.

The average farm size of higher mechanized farms, it was found, was greater that the farm size beyond which the labour input per acre would be more on higher mechanized farms in both the studies except bullock operated-tubewell irrigated farms in the bet type of farming area in the Punjab study where the two farm sizes were just equal. It showed that the mechanization, would shift the employment curve upward at farm sizes beyond what was less than the average farm size observed in the data.

Graphical Interpretation

The regression lines of labour input per acre on farm size show clearly what has been explained so far. The employment curves for the Farm Management study and the Punjab study are given in **Fig.** 2 and 3 respectively. For the Ferozepur study, the curves of labour input per acre against farm size within the observed farm size ranges were higher for tractor operated farms than for the bullock operated farms during both the years. It clearly showed that the employment curve shifted upward with the increase in the level of mechanization. One thing more, whereas during 1968-69, the employment curve for tractor operated farms was throughout above the one for bullock operated farms, but during 1969-70, the employment curve for tractor operated farms, though at higher level within the observed farm size range, when extrapolated backward, intersects the employment curve for bullock operated farms at point p. This means that only on farms of size greater than OM (13.57) the employment on tractor operated farms would be higher.

In case of the Punjab data, there were as many as 8 curves, one corresponding to each farm classification, and to avoid too much mess in **Fig.** 3 only few comparisons were elaborated. First, compare bullock operated-persian wheel irrigated (Curve

Table 4. The farm size beyond which labour input per acre is greater on farms with higher level of mechanization in Punjab.

S. No.	Farm classification with level of mechanization Lower	Upper	Relevant farm size (Acres)	Average farm size of higher mechanized farms (Acres)
	Farm Management Study, Ferezepur:			
I.	1968–69			
	(i) Bullocks	Tractor	-ve	41.00
II.	1969–70			
	(ii) Bullocks	Tractor	13.57	44.62
	Punjab Study:			
I.	Non-bet type of farming area:			
	1. Persian wheel irrigation	Tubewell irrigation	10.23	12.07
	2. Persian wheel + canal irrigation	Tubewell + canal irrigation	10.22	14.36
	3. Bullock (with tubewell)	Tractor	12.00	35.01
	4. Bullock (with tubewell plus canal)	Tractor	16.96	35.01
II.	Bet type of farming area:			
	5. Persian wheel irrigation	Tubewell irrigation	19.66	19.16
	6. Bullocks	Tractor	-ve	40.21

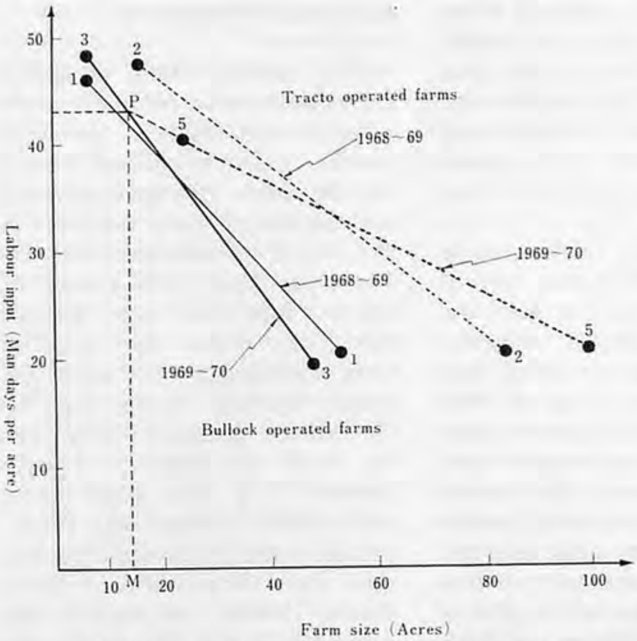

Fig 2. Regression lines of labour input per acre on farm size for different levels of mechanized farms, Ferozepur.

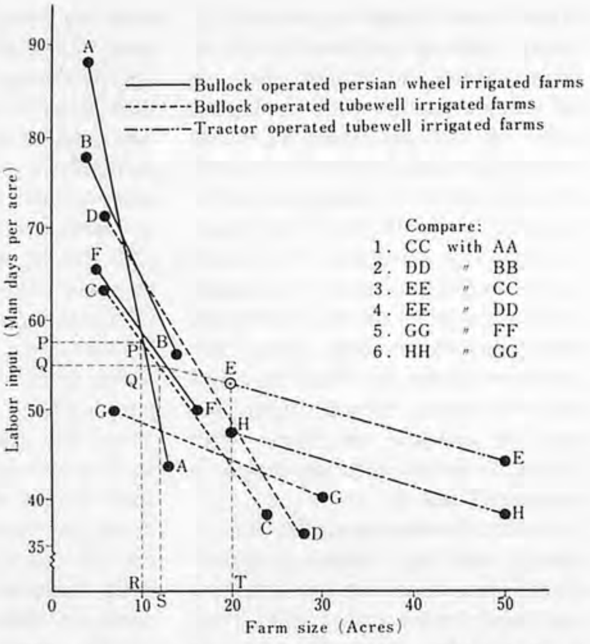

Fig 3. Regression lines of labour input per acre on farm size for different levels of mechanized farms, Panjab.

AA) with bullock operated-tubewell irrigated (Curve CC) farms to show the effect of tubewell mechanization on labour employment in the non-bet type of farming area. The two curves intersect at point P beyond which the Curve CC is at a higher level than the curve AA. It shows that the labor employment potential on farm sizes of greater than OR operated with bullock and irrigated with persian wheel can be exploited if tubewell irrigation is introduced. Similarly, compare the curve CC with EE to show the effect of tractor on employment. They do not intersect because the minimum farm size with tractor was found to be 20 acres at which the labour employment on bullock operated farms was less than that on this farm size with tractor. The curve EE, when extrapolated backward, meets the curve CC at Q with farm size OS. It shows that on sizes beyond OS, the labour employment would be higher on tractor operated farms but there were no tractors observed on farm sizes of less than OT. What to do and suggest in such cases? Since, there were bullock operated farms beyond 20 acres, they should shift to tractor power, and hire out the surplus potential to small farms to enable them to shift to curve EE instead of QC.*

In the bet type of farming area the comparison of bullock operated (Curve GG) and tractor operated (Curve HH) farms shows an upward shift in the employment curve throughout. Again, this shows that the labour employment potential can be better created and exploited by having large farms where mechanization can be resorted to rather than sustaining on the existing lower placed employment curve through slicing of the farm size.

Permanently Hired Labour input

Strictly speaking, it is the hired labour input that is more crucial for policy implication. Since permanent labour input, comprising of family labour and permanently hired labour is more or less fixed input that does not vary in some good range of farm size, only average picture on different farm situations is presented here.

In the Ferozepur study, both the family labour and permanently hired labour were found to be higher on tractor operated farms than on bullock operated farms (**Table** 5). There were 2.619 and 2.571 men per farm of family labour on tractor operated farms during 1968-69 and 1969-70 respectively as compared to 2.000 and 2.050 men per farm of family labour on bullock operated farms during these years respectively. Correspondingly, the permanently hired labour men per farm were 1.571 and 1.905 on tractor operated farms and 1.159 and 0.925 on bullock operated farms during 1968-69 and 1969-70 respectively.

In the Punjab study, the family labour input on different farm situations varied in a narrow range of from 2.162 to 2.536 and from 2.426 to 2.725 men per farm in the non-bet and bet type of farming area respectively (**Table** 5). But the permanently hired labour varied from 0.075 to 1.571 and from 0.188 to 1.907 men per farm in the non-bet and bet type of farming areas respectively. The permanently hired labour in-

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* The extent of hiring different farm machineries on different farm situations is discussed in a later section.

Table 5. Family labour and permanently hired labour input on different farms with varying levels of mechanization in Punjab.

S. No.	Farm classification with source of Draft power	Irrigation	Family labour per farm	Family labour per acre	Permanently hired labour per farm	Permanently hired labour per acre
	Farm Management Study, Ferozepur:					
I.	1968–69:					
1.	Bullock	Tubewell	2.000	0.085	1.159	0.049
2.	Tractor	Tubewell	2.619	0.064	1.571	0.038
II.	1969–70					
3.	Bullock	Tubewell	2.050	0.097	0.925	0.042
4.	Tractor	Tubewell	2.571	0.058	1.905	0.043
	Punjab Study:					
I.	Non-bet type of farming area:					
A.	Bullock	Persian wheel	2.475	0.343	0.075	0.010
B.	Bullock	Persian wheel plus canal	2.500	0.265	0.238	0.025
C.	Bullock	Tubewell	2.162	0.179	0.662	0.058
D.	Bullock	Tubewell plus canal	2.475	0.173	0.775	0.054
E.	Tractor	Tubewell	2.536	0.072	1.571	0.046
II.	Bet type of farming area:					
F.	Bullock	Persian wheel	2.725	0.260	0.188	0.018
G.	Bullock	Tubewell	2.512	0.131	0.825	0.046
H.	Tractor	Tubewell	2.426	0.060	1.907	0.047

put increased from 0.075 men on persian wheel irrigated farms to 0.662 men on tubewell irrigated farms in the non-bet type of farming area. Again, on farm situations where the irrigation sources were complemented with the canal water, the permanently hired labour input increased from 0.238 to 0.775 men per farm respectively. Likewise, in the bet type of farming area, the permanent hired labour in put was 0.188 and 0.825 men per farm on persian wheel and tubewell irrigated farms respectively. On tractor operated farms, the permanent labour input was still higher at 1.571 and 1.907 men per farm in the non-bet and bet type of farming areas respectively.

Again, on per acre basis, which is the real concern of the policy, the permanently hired labour showed a significant increase from 0.010 and 0.018 to 0.058 and 0.046 men per farm on persian wheel and tubewell irrigated farms in the non-bet and bet type of farming areas respectively. On tractor operated farms there was some decline in the permanently hired labour input per acre to 0.046 men in the non-bet type of farming area whereas there was only little increase to 0.047 men in the bet type of farming area. But before making any hasty conclusion the causal labour input should also be examined.

Casually Hired Labour Input

The causually hired labour, a variable input, was also analysed with simple linear regression which are given in **Table. 6.** In case of Feroz-epur study, it had very low correlation with farm size. The coefficient 'b' in the linear regression was also very small. However, it was positive for bullock operated farms and negative for tractor operated farms. But the value of constant 'a' which shows the level at which the casual labour employment curve would start was higher in case of tractor operated farms. It was 11.26 and 10.22 during 1968-69 and 1969-70 respec-

Table 6. Linear relationship between casually hired labour input per acre and farm size on different farms with varying levels of mechanization.

S. No.	Farm Classification with Draft power	Irrigation	Linear regression of casually hired labour input per acre on farm size $Y = a + bX$	Simple correlation
	Farm Management Study, Ferozepur			
I.	1968–69			
1.	Bullock	Tubewell	$Y = 5.56 + 0.0534 X$	0.1326
2.	Tractor	Tubewell	$Y = 11.26 - 0.0547 X$	–0.1716
II.	1969–70			
3.	Bullock	Tubewell	$Y = 6.39 + 0.0443 X$	0.1222
4.	Tractor	Tubewell	$Y = 10.22 - 0.0390 X$	–0.1332
	Punjab Study:			
I.	Non-bet type of farming area:			
A.	Bullock	Persian wheel	$Y = 3.43 + 0.9166 X$	0.5492**
B.	Bullock	Persian wheel + canal	$Y = 4.67 + 0.8043 X$	0.4869**
C.	Bullock	Tubewell	$Y = 11.52 + 0.3037 X$	0.3244*
D.	Bullock	Tubewell + canal	$Y = 11.42 + 0.2575 X$	0.3499*
E.	Tractor	Tubewell	$Y = 11.62 + 0.1322 X$	0.2867
II.	Bet type of farming area:			
F.	Bullock	Persian wheel	$Y = 6.28 + 0.3739$	0.3178*
G.	Bullock	Tubewell	$Y = 12.54 + 0.1646 X$	0.3849*
H.	Tractor	Tubewell	$Y = 12.56 + 0.1138 X$	0.2430

* Significant at 0.05 probability level ** Significant at 0.01 probability level

tively as compared to 5.56 and 6.39 only in case of bullock operated farms during these years respectively.

In the Punjab study, the casual labour input, in contrast to total labour input which showed negative relationship with farm size, was found to be positively associated with farm size in all the farm classifications. All the linear regression coefficients were positive. But the more interesting result was that the linear regression coefficient showed a decline with the increase in the level of mechanization. It decreased from 0.9166 on persian wheel irrigated farms to 0.3037 on tubewell irrigated farms and further to 0.1322 on tractor operated farms in the non-bet type of farming area. Also, whereas the former two coefficients were statistically significant, that of tractor operated farms was not significant implying that it was not significantly different from zero. Similarly, in the bet type of farming area, the 'b' values on persian wheel irrigated, tubewell irrigated and tractor operated farms were 0.3739, 0.1646 and 0.1138 respectively, the former two being significant and the last one not significant.

The pure constant intercept values showed a significant increase from 3.43 on persian wheel irrigater farms to 11.52 on tubewell irrigated farms; from 4.67 on persian wheel plus canal irrigated farms to 11.42 on tubewell plus canal irrigated farms in the now bet area; and from 6.28 on persian wheel irrigated farms to 12.54 on tubewell irrigated farms in the bet area. On tractor operated farms, the pure constant intercepts were 11.62 and 12.56 in non-bet and bet type of farming areas respectively. Thus, the starting point for casually hired labor input per acre on mechanized farms with tubewell only or with both tractor and tubewell showed a tendency to stabilize at around 11.5 in the non-bet area and around 12.0 in the bet area, which were far higher than the non-mechanized farms. From this common base, the casually hired labour input showed an increase with the increase in farm size at a higher rate on tubewell irrigated farms than on tractor operated farms.

Hiring of Different Input Factors

Farming efficiency in relation to inter-farm dependency with respect to hiring in/out of different inputs has been advocated elsewhere (14). This is more true of farm machinery which is the crux of this article. The proportion of farmers hiring different types of machinery on different farms with varying levels of mechanization is given in **Table 7**, for the Punjab study only from which the relevant data on this aspect were available. It shows that on persian wheel irrigated farms, a larger percentage of farmers hired irrigation water than the tractor. But on bullock operated tubewell irrigated farms where the owned source met the irrigation requirements, a large percentage of farmers hired the tractor to supplement their draft power of bullocks.

The money spent on hiring different machinery inputs on different types of farms, as given in **Table 8**, showed that Rs. 8.12 and 7.60 per acre were spent on hiring irrigation water which formed 21.30 and 20.51 per cent of the total irrigation cost on persian wheel and persian wheel plus canal irrigated farms respectively in the non-bet type of farming area. Compared to this, only Rs. 1.31 and Rs. 3.24 per acre were spent for hiring the tractor which formed 2.25 and 5.83 per cent of the total cost on draft power on these farms respectively. In the bet type of farming area, also, Rs. 8.38 and 1.54 per acre were spent for hiring the irrigation water and tractor respectively on persian wheel irrigated farms.

On tubewell irrigated farms, owing to sufficient irrigation water availability, the expenditure for tractor hiring was more than on persian wheel irrigated farms. It was Rs. 5.95 and 5.41 per acre on tubewell and tubewell plus canal irrigated farms respectively in the non-bet area and Rs. 4.06 per acre on tubewell irrigated farms in the bet area. Similarly, hiring of other machinery was more on persian wheel irrigated farms than on tubewell irrigated farms and the least on tractor operated farms.

Apparently, these services of irrigation water and of tractor are made available to the small farmers by the large farmers from their surplus potential and the small farmers, thus also ben-

Table 7. Proportion of farmers hiring different input factors on different farms with varying levels of mechanization.

S. No.	Farm classification with source of		Irrigation	Tractor	Other machinery
	Draft power	Irrigation			
I.	Non-bet type of farming area:				
A.	Bullock	Persian wheel	72.50	15.00	75.00
B.	Bullock	Persian wheel plus canal	65.00	30.00	92.50
C.	Bullock	Tubewell	5.00	37.50	80.00
D.	Bullock	Tubewell plus canal	20.00	40.00	62.50
E.	Tractor	Tubewell	0	0	53.57
II.	Bet type of farming area:				
F.	Bullock	Persian wheel	80.00	20.00	67.50
G.	Bullock	Tubewell	7.50	45.00	52.50
H.	Tractor	Tubewell	0	0	55.56

Table 8. Hiring of different input factors on different farms with varying levels of mechanization.

S. No.	Farm classification with source of Draft power	Farm classification with source of Irrigation	Irrigation: Average cost per acre (Rs.)	Irrigation: Hiring cost (Rs.)	Irrigation: Hiring as%age of av. cost	Tractor: Average cost per acre (Rs.)	Tractor: Hiring cost (Rs.)	Tractor: Hiring as%age of Av. cost	Other machinery *: Average cost per acre (Rs.)	Other machinery *: Hiring cost (Rs.)	Other machinery *: Hiring as%age of av. cost
I. Non-bet type of farming area:											
A.	Bullock	Persian wheel	38.78	8.12	21.30	58.18	1.31	2.25	22.04	16.76	43.20
B.	Bullock	Persian wheel plus canal	37.06	7.60	20.51	55.59	3.24	5.83	24.34	20.30	45.47
C.	Bullock	Tubewell	70.14	0.23	0.33	66.04	5.95	9.01	17.43	10.54	37.68
D.	Bullock	Tubewell plus canal	54.92	2.40	4.37	63.86	5.41	8.47	14.36	9.25	39.18
E.	Tractor	Tubewell	43.45	0	0	117.29	0	0	14.08	1.30	8.45
II. Bet type of farming or area:											
F.	Bullock	Persian wheel	31.78	8.38	26.37	47.68	1.54	3.04	14.83	11.37	43.40
G.	Bullock	Tubewell	46.39	0.42	0.90	58.69	4.06	6.91	14.14	8.58	37.76
H.	Tractor	Tubewell	41.67	0	0	110.72	0	0	10.49	1.52	12.66

* The average cost per acre was exclusive of hiring cost. Hiring as percentage of average cost was thus calculated after adding the two.

efit from these services.

These results were also supported from the data available in another study, cost accounting one, on the farm business analysis for Ludhiana (IADP) District during 1971-72 (15). The expenditure on hiring in machinery and the receipts from hiring out machinery on different categories of farms are given in **Table 9.** It shows that on per cultivated cropped acre basis, the expenditure on hiring in machinery was the maximum on medium farms and the minimum on large farms. Again, it was less on tractorized holding than on non-mechanized ones being Rs. 8.96 and 21.29 per cropped acre respectively.

The income from hiring out the machinery was far higher on large and tractorized holdings than on other farms. Also, it was far higher than the expenditure incurred on hiring in the machinery on these holdings. Thus, on large farms the income from hiring out and expenditure on hiring in the farm machinery were Rs. 70.25 and 16.75 per cultivated acre respectively. On tractorized holdings, these figures were Rs. 91.71 and 16.33 respectively as compared to Rs. 1.34 and 41.11 on non-tractorized holdings respectively. On medium farms, the expenditure on hiring in machinery was higher than the receipts from hiring out the machinery by Rs. 4.36 per cultivated acre and on small farms there was no hiring out of the farm machinery, they only hired in the machinery.

Thus, the interdependency of various farms with respect to hiring in/out of different machinery investments with surplus potential, and large farms hiring out relatively more and small farms hiring in relatively more, stand confirmed.

REFERENCES

1. Billings, Martin H. and Arjan Singh. 1971 The Effect of Technology on Farm Employment in India. Dev. Digest. 9(1) : 98-107.
2. Eicher, Carl, et.al. 1970 Employment Generation in African Agriculture. Institute of International Agriculture, research report No. 9, East Lansing, Michigan State University.
3. Grewal, S.S., 1972 Impact of Mechanization on Labour Employment and Labour Productivity in Punjab Agriculture. Ph.D. Dissertation, Punjab Agricultural University, Ludhiana (unpublished).
4. Johl, S.S. 1971 Mechanization, Labour Use and Productivity in Agriculture. Deptt. of Agricultural Economics and Rural Sociology, The Ohio State University, U.S.A., Occasional Paper No. 23.
5. Kahlon, A.S. et.al. 1971. Studies in Economics of Farm Management, Ferozepur District (Punjab). Deptt. of Economics and Sociology, PAU, Ludhiana.
6. Kahlon, A.S. and Karam

Table 9. Expenditure on hiring in and income from hiring out machinery on different farm categories, Ludhiana (IADP) District, 1971–72. (Unit: Rupees)

Farm category	N	Expenditure on hiring in machinery: Per farm	Expenditure on hiring in machinery: Per cultivated acre	Expenditure on hiring in machinery: Per cropped acre	Expenditure on hiring in machinery: Percentage to total operating expenses	Income from hiring out machinery: Per farm	Income from hiring out machinery: Per cultivated acre	Income from hiring out machinery: Per cropped acre
Small	7	190.29	20.53	10.47	3.02	–	–	–
Medium	10	615.50	39.50	20.72	5.39	547.60	35.14	18.43
Large	7	522.00	16.75	9.12	2.32	2189.00	70.25	38.25
Tractorized	8	458.63	16.33	8.96	2.21	2574.88	91.71	50.33
Non-Tractorized	9	682.22	41.11	21.29	5.80	22.22	1.34	0.69

Source: Singh J. N., 1972. Report of Farm Business Analysis for Ludhiana (IADP) District, Punjab, 1971–72. Department of Economics and Sociology, Punjab Agricultural University, Ludhiana (Mimeographed).

Appendix. 1. The results of log-linear relationship between labour input per acre and farm size on different farms with varying levels of mechanization, Punjab.

S. No.	Farm classification with source of Draft power	Irrigation	Values in the regression : log Y = log a + b log X Log a	b	Correlation (r)
I.	Non-bet type of farming area:				
A.	Bullock	Persian wheel	2.2779	−0.5341	−0.5372**
B.	Bullock	Persian wheel plus canal	2.1650	−0.3935	−0.4973**
C.	Bullock	Tubewell	2.0035	−0.2682	−0.4181**
D.	Bullock	Tubewell plus canal	2.1488	−0.3676	−0.6654**
E.	Tractor	Tubewell	1.8021	−0.1581	−0.2520
II.	Bet type of farming area:				
F.	Bullock	Persian wheel	2.0198	−0.2783	−0.4182**
G.	Bullock	Tubewell	1.8479	−0.1687	−0.3692*
H.	Tractor	Tubewell	1.7221	−0.1283	−0.6456**

* Significant at 0.05 probability level ** Significant at 0.01 probability level

Singh. 1970. Application of Partial Budgeting Technique to Farm Business Problems. Punjab Agril. University, Ludhiana. 33-47.

7. Rao, C.H. Hanumantha. 1972. Ceiling on Agricultural Land Holdings-Its. Economic Rationale. Econ. and Pol. Weekly. Rev. of Agr. June, 1972. A-59-A-62.
8. Rao, C.R., 1952. Advanced Statistical Methods in Biometric Research. John Wiley, New York., U.S.A., 112-14.
9. Rudra, Ashok, 1971 Employment Patterns in Large Farms OF Punjab. Economic and Pol. Weekly, Rev. of Agri. June, 1971. A-89-A-94.
10. Sarkar, K.K. and M. Prahladachar. 1966. Mechanization as a Technological Change. Ind. J. Agri. Econ. 21(1) : 171-82.
11. Singh, Arjan. 1971. The Effect of Technology on Farm Employment in India (A long term perspective). USAID, New Delhi (Mimeo)
12. Singh, Karam, 1971. Resource Adjustment Possibilities and Resource Use Efficiency in Punjab Agriculture. Ph.D. Dissertation, Punjab Agricultural University, Ludhiana (Unpublished).
13. Singh, Karam and Kuldip Grewal, 1972. Labour Employment Pattern on Punjab Farms. Unpublished.
14. Singh, Karam and Rajinder Sondhi, 1972. Farm Size Economic Efficiency and Resource Requirements Economic Affairs. 17(11) : 524-32.
15. Singh, J.N., 1972. Report of Farm Business Analysis for Ludhiana (IADP) District, Punjab. 1971-72. Department of Economics and Sociology, Punjab Agricultural University, Ludhiana.
16. Thorbecke, Erik, 1970. Unemployment and Under-Employment in Latin America. (Mimeograph), A paper prepared for Interamerican Bank.
17. Thorbecke, Erik, 1970. Unemployment and Under Employment in the Developing World. Pearson Conft. Doc. No. 29, Columbia Univ. Conf. on International Econon. Dec.
18. Turnham, David, 1970. The Employment Problem in the Less Developed Countries (A Review of Evidence). Paris OECD, Dev. Centre.

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Appendix II. F - values calculated from the test of the equality of regression equations for different levels of mechanization.

Farm situations compared		F - value
I. Farm Management Studies, Ferozepur:		
1. 1968–69:	Tractor vs Bullocks (1 and 2)	3.648* (2,61)
2. 1969–70:	Tractor vs Bullocks (3 and 5)	6.438** (2,57)
II. Punjab Study:		
Non-bet type of farming area:		
3.	Tubewell vs persian wheel (C with A)	35.782** (2,76)
4.	Tubewell + canal vs persian wheel plus canal (D with B)	2.988 NS (2,76)
5. Trac	Tractor vs bullocks (E with C)	3.958* (2,64)
6.	Tractor vs bullocks (E with D)	10.256** (2,64)
Bet type of farming area:		
7.	Tubewell vs Persian wheal (G with F)	6.848** (2,76)
8.	Tractor vs Bullocks (H with G)	4.208* (2,63)

Note: Figures in the parenthesis are the degrees of freedom
* Significant at 5 per cent level ** Significant at 1 per cent level
NS Not significant at 5 per cent but significant at 10 per cent level.

A Multiphase Strategy for Agricultural Mechanization

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Introduction

In many developing countries there is no apparent agricultural labor shortage. To define benefits of mechanization and to design suitable approaches to mechanization for those areas is indeed an interesting challenge. How do you measure the value of a few extra leisure hours? How do you measure the reduced hardship in farm operations? It is clear that measurement of socilolgical and political benefits must remain subjective in nature.

The primary goal of this research proposal is to investigate how government could *better use its influence and resources* in bringing about mechanization when mechanization is deemed desirable. We hope to provide a rational method of analysis by which government planners may seek an *optimal rate or an optimal route for agricultural mechanization.*

Factors Influencing Farm Mechanization Program

The prices of agricultural products and the cost of farm machinery are two important factors affecting the development of agricultural mechanization. Subsidy payments and other means are frequently used by governments to control prices. When the mechanization status changes, strategy for price control must be changed accordingly. Indeed, dynamic assessment of the mechanization status and the effectiveness of price modification is essential in optimizing the government influence on this matter.

Interest rates on loans play an important part in the distribution of capital among various industries. When a country chooses to keep food prices low, it is generally difficult to attract capital into agricultural investment. Therefore, government influence is needed to direct capital into mechanization.

Government investment to promote improved cultural practices is also important. Extra return from increased yield may prompt the adoption of mechanization more readily than a direct equipment purchasing loan.

Government effort in improving market conditions may create farmer's interest in producing additional crops. The extra work demand together with the added income could create a very favorable condition for farmers to actively seek mechanization. Supporting facilities, which should include product processing, storage, and equipment repair will also have decisive influences on the successful implementation of mechanization.

In addition to their importance on production, irrigation and drainage affect the efficiency of machinery. Proper irrigation and drainage allow optimal scheduling of field equipment, therefore reducing machine operating cost. Hence, soil and water management is another factor which should be considered in allocating government effort for mechanization.

The factors just mentioned are in no sense exhaustive, but they do demonstrate that success of agricultural mechanization is not guaranteed by the availability of proper mechanical equipment. Any effort (public of private) spent in modifying these other factors will influence the mechanization program.

Measuring Government Effort and Effectiveness in Mechanization

Effort can be optimized only when effectiveness can be reasonably measured. It may not be too difficult to measure the effectiveness of an interest subsidy. But it is certainly not an easy task to measure the effectiveness of governmental policy on price control. In many developing countries, the price of agricultural products are under de facto government control, and it may take little effort to change the prices, but raising food prices is equivalent to the levy of a new mechanization tax. It may cause detrimental effects on other economic programs. Measuring the combined effect may therefore be very difficult.

From our point of view, it is desirable to measure the effectiveness of efforts in terms of the productivity of the farm labor force. The term "farm labor force" can be defined to mean only the currently active labor force. On the other hand, it can include all persons enagaged in agricultural production at the beginning of a mechanization program. It is obvious that the adoption of a different definition will change the basis for evaluating the effectiveness of agricultural mechanization. Therefore, a carefully defined boundary of the "system" is of utmost importance. Changing the boundary of the system may not only change the methods of analysis and measurements, but it may also change the nature of the problem itself.

Multiphase Optimization

The value of any analysis depends heavily on the accuracy of the input data used. Unfortunately, in the case of agricultural mechanization, the desired data usually does not exist. To collect data requires time and money. The systems analysis approach, indeed, may become useless to national decision makers because adequate time is usually not available. The multiphase optimization method will allow us to make use of presently available information and thereby permit starting the optimization process somewhat earlier.

Consider the way a person might navigate in a dark room by taking small cautious steps. Early movements usually will yield some information about the environment he plans to move into, which then can be used effectively to guide his next move. If he had a goal or purpose for entering the room, monitoring his present location or status with respect to his goal would help him to make a decision about his next move. The guiding of missiles to targets is accomplished by this technique. Maintaining a factory in good operating condition also takes advantage of this principle. In fact, these are the few most successful applications of optimization techniques.

In implementing an agricultural mechanization policy, generally very little information is available on how effective any effort might be. For example, how effectively a 1% subsidy on loans would promote the acceptance of equipment cannot be predicted. This uncertainty holds true for many of the other factors discussed. This lack of quantitative relationships between variables and desired results prevents the determination of an optimal strategy for implementing mechanization at early stages. Therefore, the best strategy would be to initiate selected actions on a small scale with information collection at the primary goal. Early experiences will shed useful light for the planning of the next move. Procedures and methods should be developed so that maximum knowledge can be gained and put into use immediately for making the next decision. In short, optimization decisions are modified continuously, as new information is developed. It is dynamic in the sense that factors important to agricultural mechanization development are monitored periodically, and the information is used to modify previous optimal decisions. No permanent optimal strategy is sought.

Multiphase Dynamic Model

The multiphase approach to the implementation of a mechanization program seeks to optimize the allocation of effort at each of the various phases of the program. The effort involved in each phase, the interpretation of the outcome, and the mechanics of making decisions based on this outcome must be properly planned in order to achieve optimal results. The systems analysis approach and its techniques could be very helpful. The systems approach to the solution of a problem generally includes the following procedures:

1. Define, qualitatively, the project goal, such as: mechanizing agriculture to increase labor productivity.
2. Identify the factors (or independent variables) which are believed to exert influence in attaining the goal. Variables are called "controllable" if they are expected to be modified.
3. Establish allowable limits for controllable variables and the availability of resources.
4. Determine the relationship between factors and goals. This will lead to the construction of an objective function (the goal measured as a function of all variables) and a set of constraints, which are also functions of the variables. The set of constraints and the objective function quantitatively define the behavior of the system. Collectively, they are referred to as the system model.
5. The final step is model optimization. Optimization involves the manipulation of factors to achieve an optimal goal.

We have already described briefly the mechanization goal, and identification of factors related to it. The task of determin-

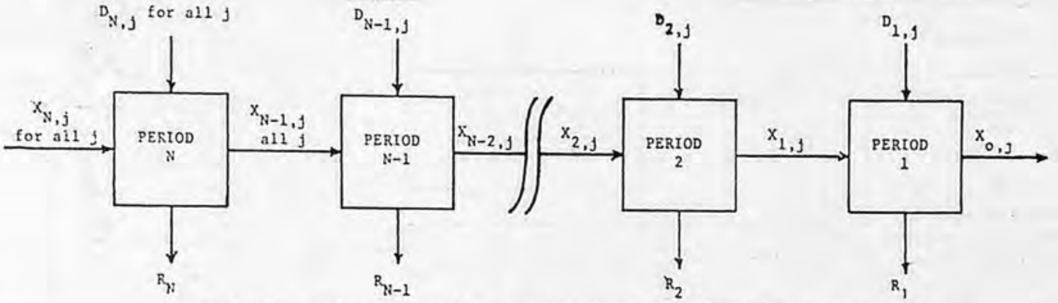

Fig 1. Schematic representation of a multiple stage mechanization project

ing relationships between factors and goals is deferred until later. The multistage approach is first modelled (see **Figure** 1) and includes the following set of relations:

$Z = \sum_i R_i$

$X_{i-1,j} = T_{ij}(X_{ij}, D_{ij})$ for all i and j ··························(1)

Where

X_{ij}: The status of the jth factor or variable having influence on mechanization at the beginning of the ith period. Machinery price, interest rate, crop yield rate and other similar influences are considered mechanization factors.

D_{ij}: The investment allocated for modifying the jth mechanization factor at the beginning of the ith period.

R_i: Increase of net farm labor productivity in the ith period due to D_{ij}.

$T_{ij}(\ )$: Function of the argument in the parenthesis where i and j denote period and variable respectively.

Z: Overall return or measure of the effectiveness of the program.

The variables R_i are also functions of X_{ij} and D_{ij}. Therefore, the model expressed in (1) can be rewritten as:

$Z = \sum_i F_i(X_{ij}, D_{ij}$ all J) for all i and $X_{i-1,j} = T_{ij}(X_{ij}, D_{ij})$ for all i and j······(1a)

Where $F_i(\ )$: Function of the arguments in the parenthesis.

When F_i and T_{ij} for all i and j are defined, the effectiveness, Z, for any decision or a set of decisions D_{ij} (all i and j) at a given initial condition, X_{Nj} for all j, can be evaluated quantitatively.

The total effort or investment, C, in the periods can be expressed as

$C = \sum_i \sum_j D_{ij}$··················(2)

With the relationship in (1a) and (2), it is possible to construct the following optimization models.

MAX $Z = \sum_i F_i(X_{ij}, D_{ij}$ all j)

$X_{i-1,j} = T_{ij}(X_{ij}, D_{ij})$ for all i and j

$\sum_i \sum_j D_{ij} \leqq B$············(3a)

Where B is the investment ceiling during the multiperiod from 1 to N,

or

MAX $Z = [\sum_i F_i(X_{ij}, D_{ij}$ all j)] $/ \sum_i \sum_j D_{ij}$

$X_{i-1,j} = T_{ij}(X_{ij}, D_{ij})$ for all i, j ···················(3b)

or

MIN $Z = \sum_i \sum_j D_{ij}$

$X_{i-1,j} = T_{ij}(X_{ij}, D_{ij})$ for all i and j

$\sum_i F_i(X_{ij}, D_{ij}$ ll j) $\geqq K$······(3c)

Where K is the minimum acceptable labor productivity increase at the end of N period mechanization program.

Depending on the characteristics of T_{ij}'s and F_i's, different optimization techniques will be used to develop an optimal policy for allocating or distributing investment among the N mechanization implementing periods. A combination of dynamic programming and other techniques would probably be resorted to for optimization. Dynamic programming may be used for optimal distribution of investment among the periods. Other techniques such as linear programming or search techniques may be used to optimize the distribution of funds in each period.

Procedures for Modeling and Optimizing a Specific Multiphase Mechanization Program

The system models discussed previously were very general. To convert the general model into a well defined useful model, one must find information that will enable him to define T_{ij}'s and F_i's relation.

The multiperiod dynamic approach proposes a gradual information collection and continued improvement of optimization. Newly obtained information will be used to update and modify future decisions. The procedure of implementing such a program is sketched schematically in **Figure** 2. The schematic drawing was prepared with emphasis on the optimization phase (items 4 and 5 of the procedure on pages 9-10). Therefore, items 1,2 and 3 were not included. Item 3 is the place where social and political factors can be injected for consideration in the systems approach to the optimal implementation of a mechanization program.

Development of Some Basic Relationships

The above section deals with the general model. The philosophy of the general model is to promote earlier starting of the optimization process without being bogged down with elabo-

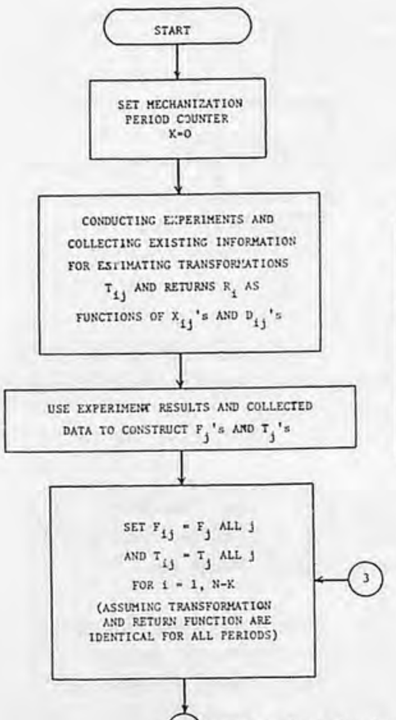

Fig 2. Optimization procedure flow chart

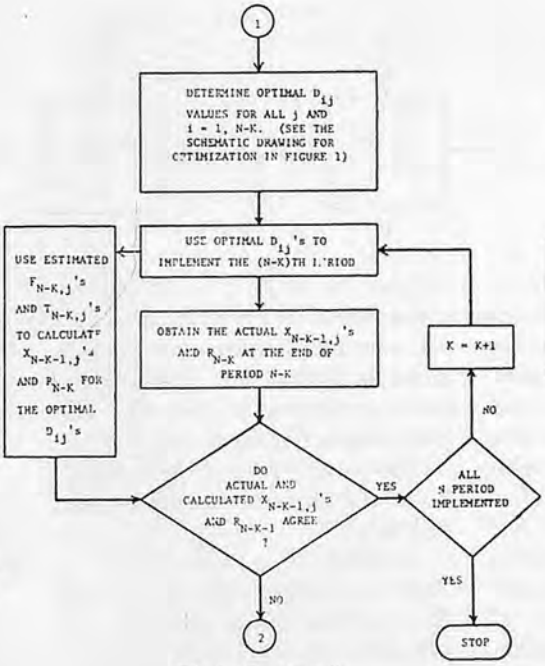

Fig 2. (Continued)

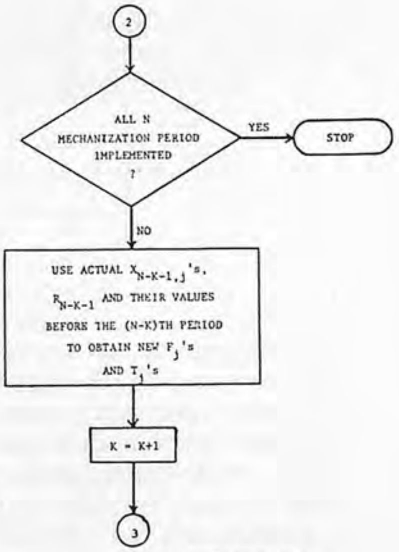

Fig 2. (Continued)

rate and endless collections of information. Nevertheless, some basic information must be collected and relationships established before the optimization process can be started. A review of recent literature*shows that, among other things, two of the important considerations in mechanization are (1) land size and shape, and (2) adequate service for equipment. Their importance to mechanization policy makers needs little discussion. Land size and shape affect equipment selection, which is a rather basic decision involving the investment of a sizeable amount of fund. They also affect equipment efficiency. However, there is usually strong resistance to land consolidation. How much governmental influence should be directed to this effort?

Adequate service actually implies two things: (1) acceptable service time and (2) reasonable service cost. Adequate service is an integral part of equipment management and as such is related to questions on ownership. Should the government encourage individual ownership, or cooperative ownership? How about government sponsored custom work stations?

The two submodels (or relationships) by themselves are not designed to answer such sophisticated questions. They probably are the minimum information needed to start the dynamic optimization of mechanization.

Submodel 1. Optimal Equipment Repair Facility Design by Simulation

The basic simulation model consists of repair channels and standly units. System constraints are (1) a maximum of P machines will be allowed to have service time (include waiting period) which exceeds T2, (2) standby equipment will be loaned to a farmer when the estimated service time (include waiting) is greater than or equal to T1.

The simulation program is event based to save computer time. **Figure** 3 shows the general outline of the program flow diagram. **Figure** 4 gives more details to a portion of the general outline.

Basically, the computer program is designed to adjust the number of service channels and number of standby equipment to minimize repair cost.

The required inputs are costs for operating repair channel, costs to increase repair channel efficiency, costs of standby units (investment and maintenance), equipment breakdown arrival rate and service rate.

The simulation program can be adjusted to take care of seasonal changes in arrival and service rates.

Type of ownership is considered to be a given parameter, it is expected that ownership may influence the numerical value as well as the regularity of arrival and service rates.

Notations for Figures 3 and 4

N: Number of idle service channels.
M: Number of idle standby equipment.
MS: Total number of standby

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* For example:"Agricultural Mechanization in South East Asia." Yoshisuke Kishida, Editor, Published by Farm Machinery Industrial Research Corp. and Shin-Norinsha Co., Ltd., Tokyo, Japan, 1971.

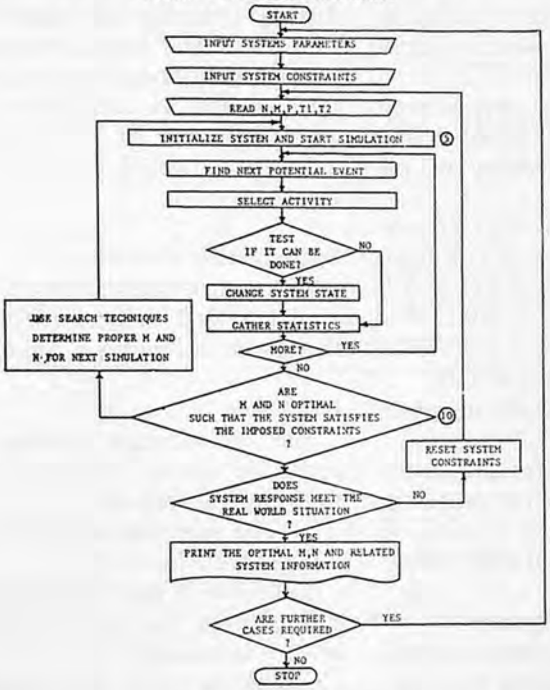
A SIMULATION MODEL FOR FARM EQUIPMENT REPAIR FACILITY WITH STANDBY UNITS

Fig 3. A general outline

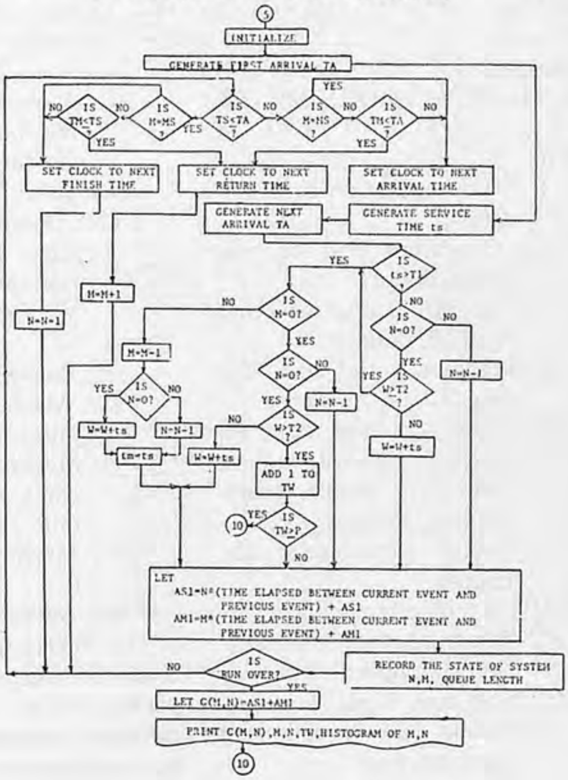
A SIMULATION MODEL FOR THE FARM EQUIPMENT REPAIR FACILITY (EVENT-ORIENTED APPROACH)

Fig 4. Detailed flow chart for ⑤—⑩

units.

t_s: Service time, hours.

P: Maximum number of equipment allowed to be turned away from service facility when queue length is such that the waiting time for the new arrival exceeds set limit, or, $W > T_2$.

W: Expected waiting time of machine, hours.

T1: Hours. Standby equipment will be loaned to the farmer when $t_s \geqq T_1$.

T2: Maximum allowable waiting time for equipment to be served, hours.

TA: Hours. Time between present arrival and the next arrival.

TM: Hours. Time remaining before the return of standby equipment.

TS: Hours. Time remaining before the next service completion.

t_m: Hours. Time that standby unit is out on loan to the farmer.

Submodel 2. Optimizing Farm Operation cost as a Function of Land Geometry, Machine Characteristics and Farm Wage

Introduction

Land size, shape and equipment characteristics such as working width and turning radius are important factors in determining field efficiencies of farm machines. Because the maneuverability of powered equipment is generally inferior to that of man-powered or animal-powered tools, careful planning of working patterns may increase equipment field efficiency. Since the cost of using farm machinery in field operation depends on both machine field efficiency and the cost of the machine, proper control of related factors could lead to a reduction of the cost.

Modern machines are usually used to replace man-or animal-powered tools. The rate of work from non-machine powered tools is slow. But their field efficiencies generally approach 100% as compared to 85% for modern farm machinery working under favorable conditions. The efficiency of modern machinery is pitifully low when land geometry and size are not favorable. In the past complete replacement of manual production was always the approach when mechanization was planned. The idea of using modern equipment to till a part of a land parcel where machine field efficiency is high and to use existing methods to complete the work may have merits and should be investigated seriously. This is especially true where rate of labor displacement must be restricted. However, dividing a piece of land in such a manner requires consideration of both efficiency and the cost of these two methods. Proper decision of this matter could be best achieved by first constructing a model such as shown in expression 5.

The Model

$$\mathrm{MIN}\ C = CM + CH$$

$$= 〔(IC+OC)/L + HP^{*}FC^{*}C_{f} + L$$

$C] \cdot TM + HC \cdot [A-(P2-P1)(Q2-Q1)/E]$ ……(5)

Subject to:

(X1, Y1), (X1, Y2), (X2, Y2), (X2, Y1) = S

Where:

C: Total operation cost, dollars.
CM: Operation cost of machine, dollars.
CH: Operation cost of other method, dollars.
IC: Machine initial cost, dollars.
OC: Other machine cost, including interest, taxes, insurance, repair, maintenance, dollars.
L: Useful machine life, hourse.
HP: Machine horsepower.
FC: Machine fuel consumption, gal/hp-hr.
C_f: Fuel cost, \$/gal.
LC: Labor cost of operating machine, \$/hr.
HC: Working cost of other method, \$/hr.
E: Working rate of other method, ft²/hr.
A: Area of the given land, ft².
(X1 Y1)
(X1, Y2): Four corner points of
(X2, Y2) the selected rectangular
(X2, Y1) land for machine operation
S: A closed set representing the points included and on the boundary of the given land.
TM: Operation time of machine, hours. It is a function of X1, X2, Y1, Y2, $\overline{W}$, $V\overline{W}$, Vt, R, OP.

Where:

$\overline{W}$: Implement width, ft.
$V\overline{W}$: Machine working speed, miles/hr.
Vt: Machine travel speed when it is not working, miles/hr.
R: Machine turning radius, ft.
OP: Operation pattern.

The model will yield quantitatively the cost changes to be expected when variables assume different values. However, the task of minimizing cost by changing variable values is not very straight-forward. Indeed, this particular model is difficult to optimize by existing optimization techniques. Straight utilization of digital computer in optimizing this model will result in prohibitively high demand on computer time. Hence, an interactive program is used so that human judgment is relied on to reduce computer work.

Optimization Procedure

The optimization procedures are described schematically by flow chart in **Figures 5 and 6.**

Discussion

The optimization process depends on human interaction on the following matters:

(1) The selection of initial machine operated area.

(2) Check if the machine area stays within the land boundary when it is enlarged.

Computers can be programmed to handle these two decision making actions. However, it would require a great deal of computer time. Limited human interaction is expected to reduce drastically the computation time needed.

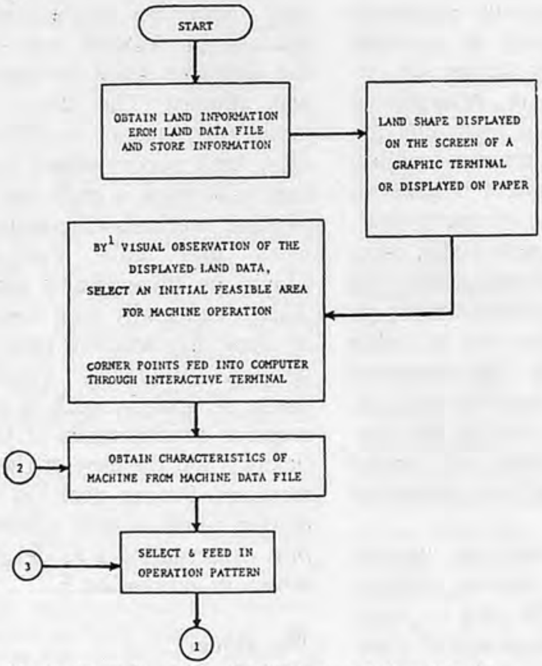

Fig 5. Procedures for obtaining a solution for the optimization model

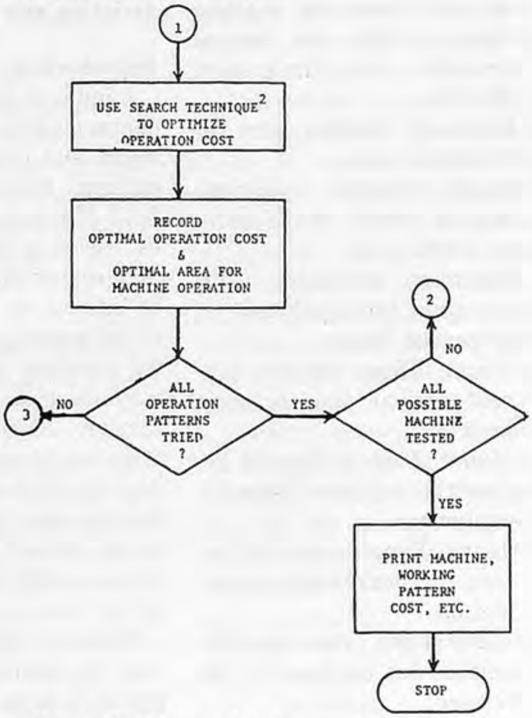

Fig 5. (Continued)…1. Use visual observation to check whether the area selected for machine operation is within the given land 2. See detailed flow chart in Fig 6.

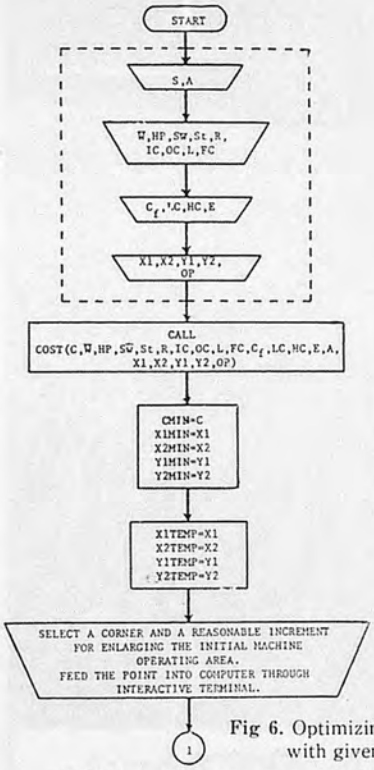

Fig 6. Optimizing operation cost for a given machine with given operation pattern

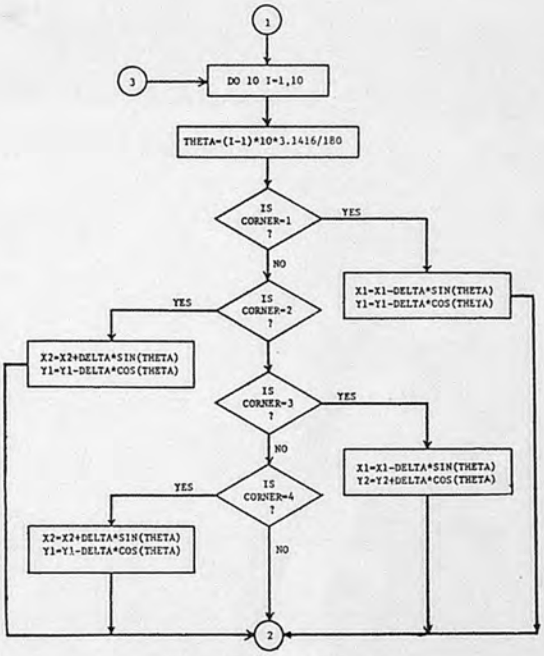

Fig 6. (Continued)

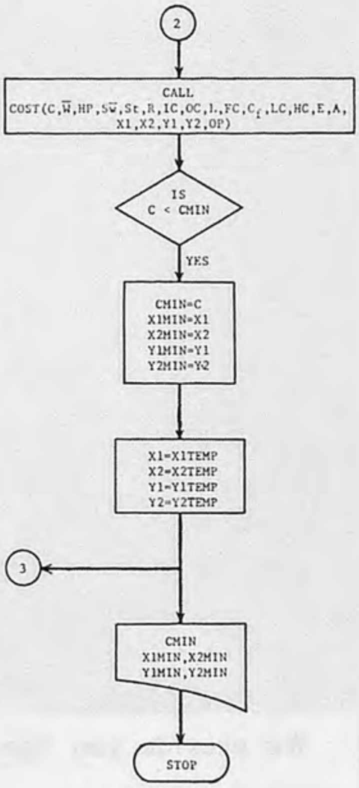

Fig 6. (Continued)

This model was constructed essentially as a submodel for the overall mechanization model. However, it may be used independently to provide the following information:

(1) For a given distribution of land, it is possible to estimate the cost of using selected existing machines without actually purchasing and testing them in the field. Considering the number of available machines on the market, it provides a possible way to evaluate their relative merits with respect to possible land consolidation schemes.

(2) It could be used by machine designers to project desirable machine characteristics.

(3) It could also be used to evaluate the land reform benefits. ■ ■

SUBROUTINE MATIME (TM,W̄,Sw̄,St,R,X1,X2,Y1,Y2,OP)

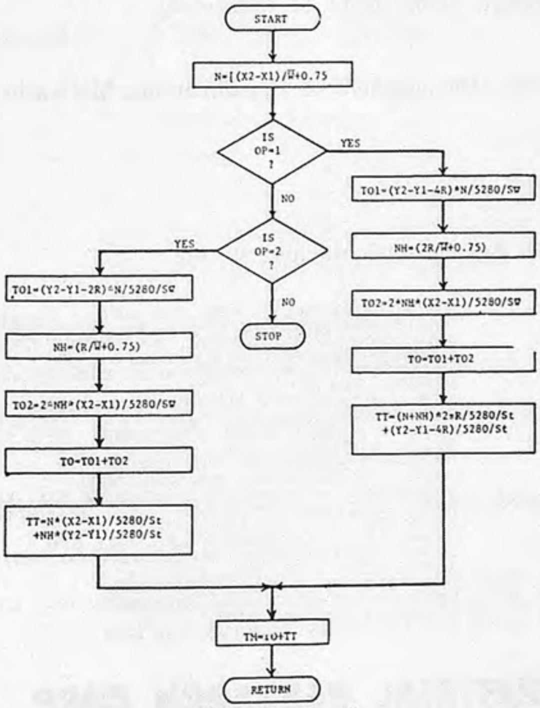

Fig 6. (Continued)

SUBROUTINE COST (C,W̄,HP,Sw̄,St,R,IC,OC,L,FC,C_f,LC,HC,E,A,
X1,X2,Y1,Y2,OP)

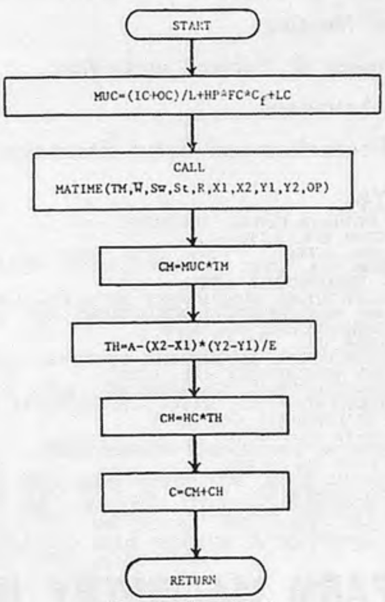

Fig 6. (Continued)

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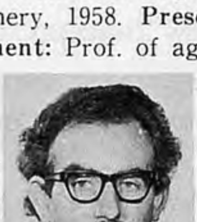
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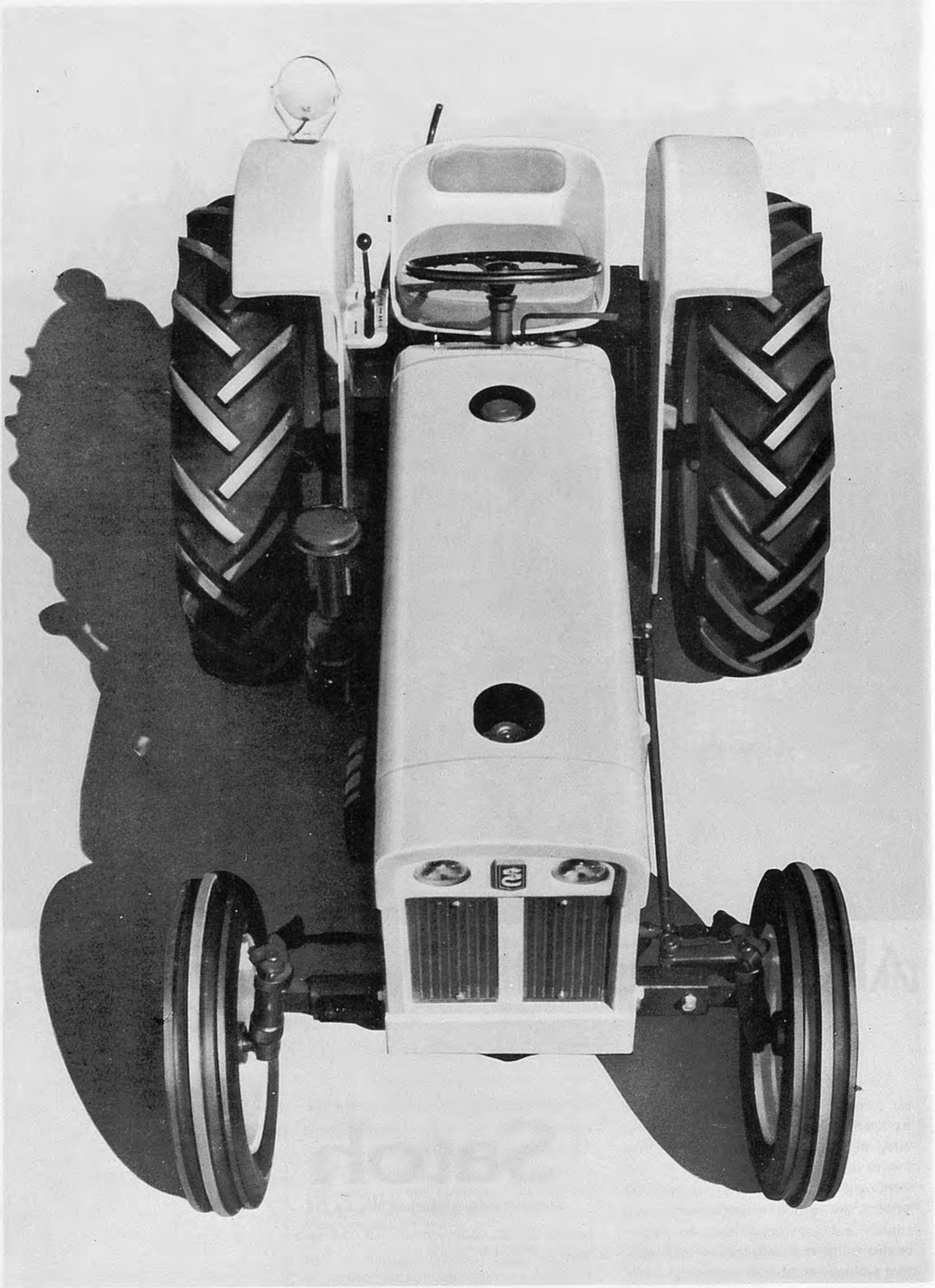

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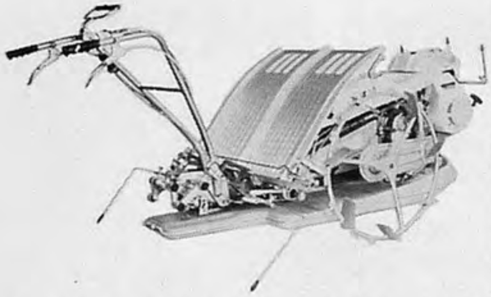

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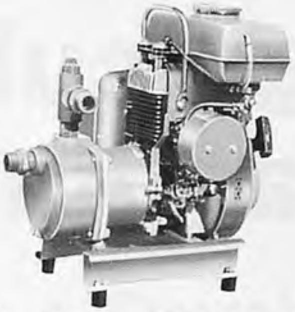

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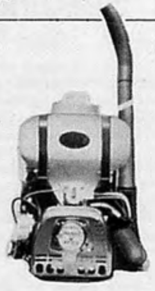

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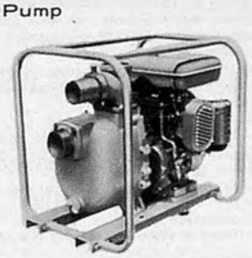

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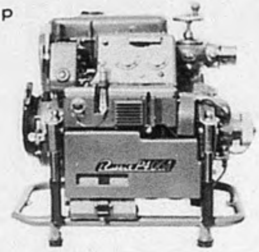

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Rice Mill Modernization, Management and Government Policy in a Developing Economy

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The rice processing industry plays a vital role in the economy of a developing country like India. The total value of food grains produced in this country is in the neighbourhood of Rs. 10,000 crores per year. The paddy crop accounts for Rs.4,000 crores or 40 percent of the total value while the wheat crop for Rs.2,000 crores. Each of the other important crops, viz., cotton, jute, tea and sugar-cane accounts for Rs.200 to Rs.300 crores every year. But it is still a traditional small-scale industry. This is because most of the rice mills, particularly in the private sector of the economy are traditional in respect of outlook, products, physical technology of production and social technology of organization and management. Probably, it would be appropriate to term the industry as partly modern as there has been a departure from the tradition to a certain extent in respect of the factors mentioned above. Realizing the importance of the industry in the country's economy, the Government of India has been trying to bring about modernization of the industry since the fifties. Although modernization has made some progress, it is yet to go a long way, particularly in the private sector.

This paper is based upon the case studies made of a few rice mills, both traditional and modern, situated in the two districts of West Bengal, during the period from January to March, 1972. The primary objective in conducting these studies is to explore some of the basic problems of modernization and the reby to provide a few guide lines for the management. To guard against embarrassment to the rice millers, identifications have been kept down to the minimum. While the area in which the studies have been made has not been kept a secret, neither the organization nor the individuals have been named. While conducting the case studies, opportunity was taken to interview people whose views have helped clarify issues involved in modernization. These people include small growers, retailers in urban and rural areas, small suppliers, employees of a lead bank and State Government officials. It is probably needless to state that a paper like this cannot leave out a consideration of government policy which can promote or thwart the process of modernization.

Preliminary Considerations

A rice miller who is contemplating to set up a modern mill or to modernize the existing one, must have a broad understanding of the economics of operation. Let it be now assumed that the miller would, in the first instance, go in for the milling equipment only. Because of heavy capital investment, the cost of production would go up considerably. If he were to make profits as he must, he would have to obtain an increased output per tonne of paddy processed. For it is the value of this output which would not only enable him to meet the higher cost of production but also to reap a surplus. To achieve this, the milling plant has to be operated to its full or near full capacity. The pre-condition for this is an adequate supply of the raw material, that is, paddy to the mill almost throughout the year.

It follows from above that the miller must have an estimate of his requirements of paddy. To have this, he must, first of all, consider the capacity of the plant to be installed, for instance, one-tonne per hour or two-tonne per hour, etc. Then he has to determine the number of hours per shift, the number of shifts per day and the total number of days to be worked in a year. From the case studies conducted earlier, it is found that in India a modern rice mill can be run for three hundred days in a year at approximately twenty to twenty-two hours of running time a day with the remaining time reserved for maintenance and repairs of the machinery. Moreover, because of traditional method of parboiling adopted in the mills in India, it is not possible to operate them in monsoons in areas where parboiling is done. It would, therefore, be reasonable to assume two hundred and fifty days and not three hundred. Next, he is to ascertain when the paddy season starts and to what period it extends. Further, he has to find out in which months the arrivals of paddy in the market are the largest so that a major part of the mill requirements may be procured during the months of peak arrivals. Apart from his own sources of information, he would do well to obtain the bulletins and other publications pertaining to the district in which the mill is situated from the marketing section of the Directorate of Agriculture of the State government and the office of the Food Corporation of India in that district.

The Milling Equipment

If the study undertaken as above indicates that there is a reasonable chance of procuring enough paddy in the area, the miller may then decide on modernization. The question which has to be decided next is the type of milling equipment to be purchased and installed. This is because which milling plant would be suitable depends on what variety of paddy it is likely to mill. In order to take the right decision in the matter, it would be imperative on the part of a miller to collect the technical data pertaining to the milling plants manufactured by different companies in India and then to have clarifications regarding these data from the organization, like the Rice Process Engineering Centre. The decision arrived at in this way would save the management a lot of botheration and trouble later on.

Capital Requirements

The case studies conducted indicate that the mills may have to build up stocks of paddy during the months in which the arrivals are the maximum. This is done in order to enable them to carry on during the lean months. Thus they have to procure their requirements of paddy within the period of two/three months even in areas where the paddy season is more than one. This is because the yield of paddy in other seasons is still small. The mills have to make an assessment of their requirements of working capital before the year commences.

The assessment is done on the basis of the prices of paddy prevailing in different months of the year together with the quantities to be purchased. After this, the next task is how to procure the amount of working capital required from time to time in the ensuing year. Some of the mills, it is learnt, do not face any difficulty at present on this account as they can make do with their own resources. But once they decide on modernization they will be required to purchase large quantities of paddy in which case they would have to face the difficulty. There are some others who are less fortunate and are in difficulties regarding working capital even now. In respect of capital cost involved in modernization, it may be pointed out that a beginning has been made in the direction of providing this type of capital to the mills. Under the lead-bank scheme of the Reserve Bank of India, initiated in 1970, branches of various nationalized banks have been set up in some areas of each district in the State.

Personnel and Their Training

With the progress of modernization, there would be need for trained personnel at various levels in a mill. While considering the requirements of personnel, it would be necessary to bear in mind certain factors, viz., the degree of modernization, the ownership pattern and the cost considerations. In most of the mills the person at the top is the owner-manager. With modernization it is essential that he should be modern-minded and more competent than before. Ordinarily, it would seem that he need not have recourse to the modern management techniques evolved, especially for big enterprises. At the same time he must realize that for efficient operation and management of his mill, he cannot do without some of these techniques, viz., costing, budget control, inventory management and marketing. It may be pointed out in this connection that these techniques, simplified and adapted, would be invaluable to him. All this clearly points to the need for formulating management training programmes geared to the needs of the small owner-manager. Moreover, the training has to be a continuing process for him if he were to keep himeself abreast of latest developments in technology and management. This means that it would be profitable for him to participate in a rice mill management programme, like the one recently organized by the Rice Process Engineering Centre in collaboration with the Indian Institute of Management, Ahmedabad.

The case studies point to the need for the appointment of two other persons at managerial level, namely, an assistant manager and a procurement officer. It may be mentioned in this connection that most of the mills in the private sector are partnership concerns, where again the partners are related to one another. It is, therefore, natural that in this set-up an outsider trained in a management institute in India will not be welcome and, particularly on a high salary. In these circumstances, it would be proper to choose two persons related to the management who are educated, comparatively young and who have shown promise and to depute them for a short period of training in management. The duration and content of the course have to be determined in consultation with the rice mills' association in a particular State in India.

It is found from the case studies that in most of the mills, the modernization resorted to is partial in the sense that only the milling operation has been modernized. It would take quite sometime before modernization is introduced in other spheres, viz., drying, cleaning, parboiling and storage. From the standpoint of the degree of modernization, it would be imperative on the part of a miller to appoint an engineer without delay. The latter would assist the owner-manager in his decision regarding the purchase and installation of the milling equipment. Once the latter has been installed, its operation would be under the charge of the engineer. In the present state of affairs, it would be sufficient to have a science graduate or a person holding a diploma, preferably in mechanical engineering and to depute him for a short course in training at the Rice Process Engineering Centre, I. I. T. Kharagpur.

It is evident from the case studies conducted that modernization necessitates the appointment of some trained personnel at the lower level. They are termed as technicians and operators and play an important role in the sense that they are ultimately responsible for proper maintenance and operation. In every mill there is a number of persons who work as helpers and who have become experienced. But to cope with the work necessitated by modernization of the milling plant, it would be necessary on the part of the management to make arrangements for their retraining in consultation with the organization, like the Rice Process Engineering Centre.

Government Policy and Modernization

The owners of the mills interviewed in the course of case studies contend that it is the government policies which stand in the way of modernization. They point out that under the Foodgrains Procurement (Levy) Order, West Bengal, the mills are to purchase different varieties of paddy at the prices fixed by the State Government from the authorized agents, like the Food Corporation of India. The paddy which they procure in this way is not at all sufficient to meet their needs. According to them, many growers who are subject to the levy order circumvent it and sell the paddy in the open market where the price is much higher. This is also true of the small growers who do not come under the purview of the levy order. Some of them sell the paddy in the open market. Some others get it hulled in the husking mills situated nearby by paying milling charges and sell the rice in the nearby markets. This apart, the paddy is processed into chira, muri, and khoi, that is, beaten rice, parched rice and parched paddy respectively. On the other hand, the mills have to sell 50* percent of their output of rice at the prices fixed by the State Government. All this, in their opinion, has created a situation in which the inefficient and uneconomic traditional mills continue to operate. They argue that as long as the ceiling prices remain, there will not be forthcoming a large supply of paddy. They, therefore, urge the State government to lift the restrictions without delay. For in that case, all would be willing to sell their paddy in the open market. This in turn will ensure a continuous supply of paddy in large quantities to the millers even in the present circumstances.

It may seem from the arguments put forward by the mill owners that all would be well once the restrictions were done away with. Before holding the government policies responsible for the present difficulties in the way of modernization, it would be appropriate at this stage to examine briefly the marketing system prevailing before the order was promulgated. An examination would reveal to what extent the price received by the farmers for their produce was fair. It may be said in this connection that the State government is committed to a policy of ensuring a fair price to the growers. This is not only meets the objective of social justice but acts also as an incentive for increased

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※ Lowered to 25 percent from June, 1972.

production.

The Marketing System

It is generally found that in the absence of restrictive measures, about 70 percent of the paddy grown comes to the local mills through two channels. First, the produce is carried to the assembling centre near a mill by the growers who are comparatively big. After preliminary inspection the wholesalers and the millers, as the case may be, offer their prices and carry on negotiations with the growers. It is the former who usually have the upper hand because of their superior knowledge of marketing condition and prices. At the same time the paddy also comes through a set of middlemen. They are known as farias and aratdars. The first three make direct purchases of paddy from the growers at the farm level and carry the same to the mills. The aratdars or stockists who purchase paddy from all sources, like growers, farias and beparis hold it for sometimes and strike a bargain by disposing it of at an opportune moment. In addition to these two agencies, there is another one through which paddy comes to the mills. This agency is known as commission agent who purchases stocks on behalf of respective mills. These commission agents and also the middlemen finance their operations by means of funds generally provided by the millers. But sometimes they depend on their own resources. It is, therefore, no wonder that these persons look more to the interests of the wholesalers or millers than to those of the growers. To facilitate understanding, the system explained above is illustrated by means of a chart as Fig.1.

It is no doubt desirable to have the various agencies as described above, generally known as middlemen, as they play an important role in effecting movement of paddy from the farm to the mills. But what is very disquieting from the standpoint of growers is that in most of the cases their price is determined by the middlemen operating in the villages and elsewhere. The reasons why they are able to exercise such a control, are not far to seek. First of all, many growers are so poor that they cannot think of storing paddy as soon as it is harvested. Consequently, they have to sell their produce entirely in the post-harvest period when the price is invariably low. These people have to borrow money from village money lenders to purchase rice in the open market at a higher price in the lean season as they are not able to set aside a portion of their output of paddy for personal consumption. But the growers who are comparatively well-off do not fare better either as they also have to part with their produce at a low price in the post-harvest period, because of acute shortage of proper storage space in their premises. Apart from the loss which they have to suffer because of having to sell their produce on the spot, they are losers in another way. Many of them are required to repay the loans in terms of paddy at a time when the next crop is harvested. Because of low prices prevailing then, they have to part with a larger amount of their produce to repay their debts. All this is in addition to the interest to be paid at a rate varying from 2 to 3 percent every month. Secondly, the lack of storage space forces most of them to keep their produce in the open. This in turn exposes it to hot and humid weather and makes it susceptible to deterioration, rottage and heavy insect attacks. As a result, there is a considerable loss in storage at growers' premises and also at the distribution points. There are, no doubt, indigenous storage places, known as "Morai" or "Golas". They are made of split bamboos and the big recepticles of mud mixed with husk or cowdung. But their number is woefully small.

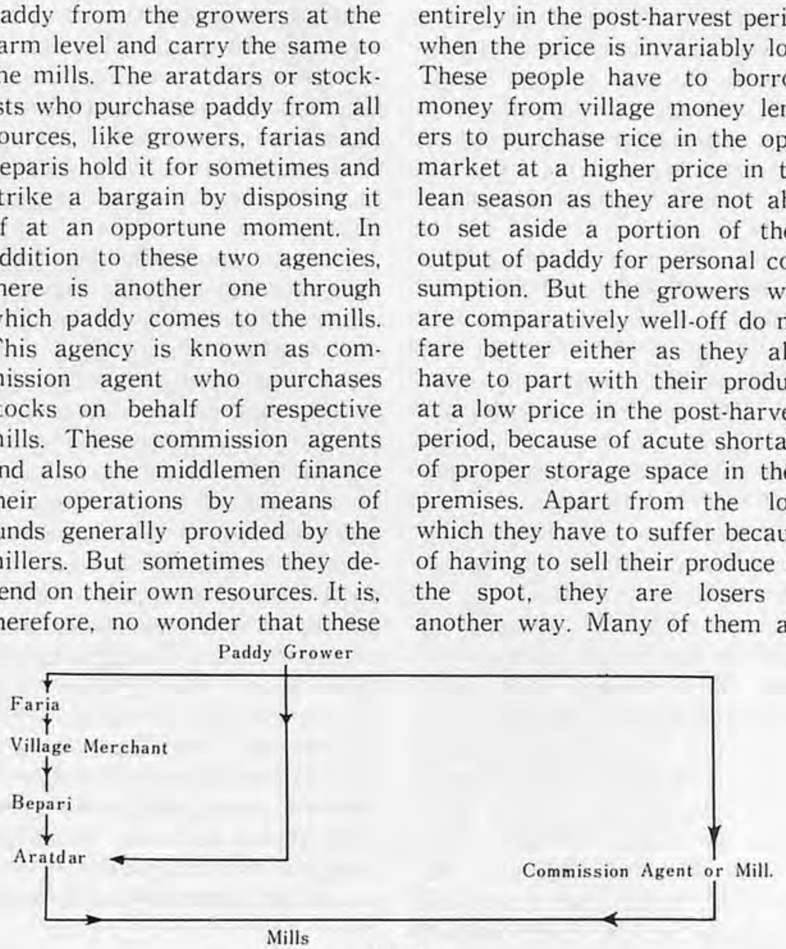

Fig. 1

The story does not end here. There are certain unauthorized charges payable by the growers in kind. These are known as 'Dhalta', 'Iswarbritti' and 'Kayali'. Even now these are realized from the farmers. For instance, there are unauthorized deductions for contribution towards charitable purposes, known as 'Iswarbritti'. Then there are deductions known as 'Dhalta' which are made to compensate for the loss in weight on account of impurities, etc. The tragedy is that even if the paddy were in tolerably good condition, there could be no escape from these charges. It can hardly be over-emphasized that with proper storage facilities at the farm level, there would neither be any loss nor any scope for these deductions. Further, there are weighment charges known as 'Kayali' which also include charges for loading and unloading. Finally, since prices of paddy are fixed by open offer or by private agreement, the growers are at a disadvantage because of lack of proper market information.

Modern paddy drying center

Moreover, they lack training to conduct negotiations with their more sophisticated rivals.

Conclusion

It is clear from the above analysis that in the absence of control measures by the State Government, there would prevail asituation in West Bengal in which the growers would find it difficult, if not impossible, to obtain a fair price for their produce. Although the government policies hamper the progress of modernization of the rice processing industry, these have to be continued as a necessary evil. It would, however, be imperative on the part of the government to make a thorough review of its policy without delay. It is gratifying to note in this connection that the government has already moved in this matter. It has been emphasized above that the development of proper marketing centres is intimately linked up with the programme of modernization. In these centres there will be provision for auction platforms, office building, wholesale shops and storage areas. The objective of organizing these centres, is to help the farmers get a fair price for their produce. This will not only promote increased production but also ensure a large marketable surplus. The latter will benefit the millers in as much as they are assured of a large supply of paddy at a reasonable price.

REFERENCES

Bhojwani N.K.: Modern Rice Mills in India: Two linked Case-studies. Indian Institute of Public Administration, New Delhi, 1968.

Desai D.K. and Patel S.M.: "Economic Implications of Modernization" in the Proceedings of the Seminar on Modernization in the Rice Industry. Indian Institute of Management, Ahmedabad, 1969.

Ensminger D.: "Modernization in the Rice Industry and Agricultural Development in India" in Seminar on Modernization in the Rice Industry, 1969. Ford Foundation, New Delhi,

Frankel F.R. "India's Green Revolution: Economic Gains and Political Costs, Oxford University Press, Calcutta.

Gupta V.K. and Desai D.K.: "Financial Implications" in the Proceedings of the Seminar on Modernization in the Rice Industry. Indian Institute of Management, Ahmedabad, 1969.

Gupta V.K. and Kothari K.B.: "Requirements of Management Skills and Personnel", in the Proceedings of Seminar on Modernization in the Rice Industry. Indian Institute of Management, Ahmedabad, 1969.

Lele Uma J.: An Analysis of Modernization of the Rice Milling Industry in India: Occasional Paper No.37 Dept. of Agricultural Economics, Cornell University, 1970.

Lele Uma J.: "Foodgrain Marketing in India: Private Performance and Public policy. Cornell University Press,Ithaca.

Marketing Branch, Directorate of Agriculture, Government of W. Bengal, Calcutta: District Handbooks on Agricultural Marketing: Burdwan, Birbhum, Howrah and Midnapore.

Rama Rao V.V. and Pandya A.C.: "Rice Processing in India", in the Rice Mill Management Progrmme, April-May, 1972, I.I.T., Kharagpur.

Staley E. and Morse R.: "Modern Small Industry for Developing Countries". McGraw-Hill Book Co., New York, 1965. ■ ■

Rice Drying with Waste Engine Heat

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The principles of operat-on of a simple, flat-bed mechanical rice dryer were investigated under simulated tropical conditions of 85°F and a relative humidity of 80%. A low drying air temperature of 95°F, that might be provided from the waste heat from the blower engine, was compared to higher temperatures of 110°F and 125°F. A low air flow rate of 10 cfm/ft^2 of dryer bed area was also compared with a higher air flow rate of 30 cfm/ft^2. The typical uninterrupted, undisturbed drying procedure was also compared with 1) periodic stirring of the bed of rice, 2) periodic reversal of air flow, 3) short duration tempering, and 4) a combination of periodic air flow reversal and short duration tempering.

Measurements were made of 1) moisture removal rate, 2) the variation of temperature throughout the drying bed, 3) the variation of moisture content throughout the drying bed when an average 13% m.c.w.b. had been attained and 4) yields of head rice from samples taken from different levels of the drying bed. Air delivery characteristics were determined for two small fans driven by small single-cylinder engines that might be used for small flat-bed grain dryers in rural areas where electricity is not available.

The controllable variables of this rice drying investigation were designed to evaluate the small flat-bed grain dryer for farm and village level conditions in developing countries. Multiple cropping in the tropics with improved rice varieties forces some harvesting to be done during the wet rainy seasons when sun drying is not possible.

Many of the new heavier yielding rice varieties tend to shatter more easily compared to the traditional indiginous varieties. To minimize shattering losses the new rice varieties must then be harvested promptly when mature, even though at a high (20 to 25%) moisture content, and threshed immediately with a minimum of handling. The result is then a greater yield of high moisture rough rice that will begin to deteriorate in a few days if not dried as compared to considerable field drying of stalk grain in the past. (Esmay, et al, 1971)

Experimental Procedure

The experimental drying chamber was an open ended plywood box 16 x 16 in. in cross section and 12 in. deep. An alternate 24 in. deep box was used for the deeper rice bed tests. A screen wire through which air but not

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The authors wish to express their appreciation to S. M. Henderson, Professor of Agricultural Engineering, University of California at Davis for his advice and assistance in running these drying tests and for the use of his laboratory.

rough rice would pass, was placed at the bottom of the drying chamber over the plenum chamber. A second screen wire could be placed over the 12 in. deep drying bed and the complete chamber inverted for the study of air reversal drying. The inverting was done in less than a minute with a small hoist. The drying chamber was supported on a sensitive scale during the drying tests for a continuous measurement of moisture removal.

The air supply to the drying chamber was controllable with dampers, heaters, and humidifiers. Ambient air supply conditions were held constant at 85°F and 80% RH or 118 Grains moisture per pound which equals 0.0168 lb/lb. Air flow to the drying chamber was measured through an orifice plate and air and grain temperatures were measured with thermocouples.

Early Rose (nonglabrous variety) rough rice was used for the experimental studies. The rice was grown and harvested in the Sacramento Valley of California during the summer of 1972 and the experimental tests were run in the research laboratories of the Agricultural Engineering Department at the University of California at Davis. The rough rice average 20% m.c.w.b. at arrival in the research lab and was stored at low temperature at this moisture level for the subsequent drying tests.

Milling tests were made on 1500 gram rice samples taken from 3 or 5 different levels of the dryer bed at the end of each drying test. For the 6 inch drying bed tests three samples were taken from 1 inch above the bottom, 1 inch from the top and the middle. For the 12 inch and 24 inch drying bed tests, five evenly spaced samples were taken with the top and bottom ones also 1 inch from the top and bottom surfaces. A number of control samples of the incoming moist rice were also taken and were slowly air dried in the laboratory room.

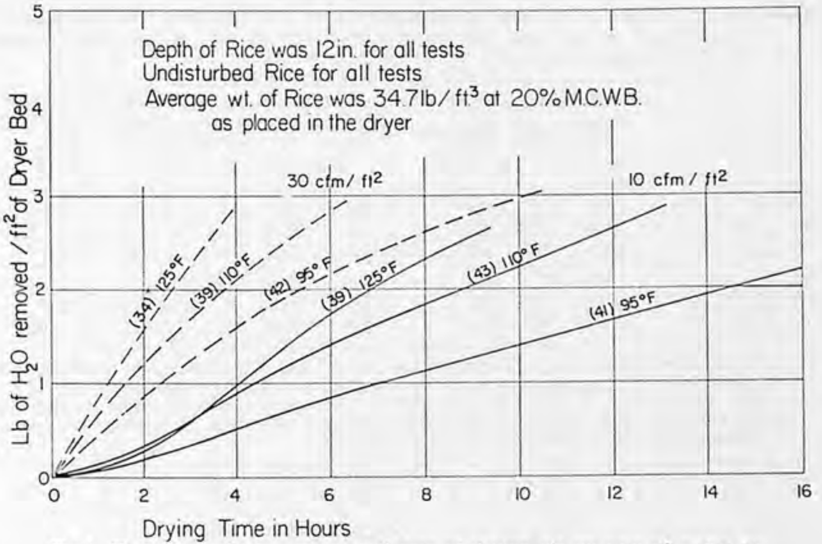

Fig.1. The effect of temperature and rate of drying air on rate of water removal. ※Number in parentheses represents the average head yield in percent after milling. Average head yield for the control (room dried) samples was 42.75 percent.

Results and Discussion

The principal results of the drying tests are shown on four graphs which plot water removal against time. The water removal is in pounds per sq. ft. of drying bed area. This holds regardless of the air flow rate, air temperature or depth of drying bed. All rice was approximately 20% m.c.w.b. at the beginning of tests and was dried to an overall average of approximately 13% m.c.w.b. The weight of the 20% rough rice as placed in the experimental dryer was an average of 34.7 lb/ft^3 (approximately 27.8 lb of dry matter) for all except the reversal tests. For the reversal tests the rice was gently packed into the dryer bed and covered with a second screen so it might be inverted with a minimum of disturbance to the rice.

Fig. 1 presents the experimental results for evaluating the effect of drying air temperature and rate of air movement through the rice. For this set of tests the drying bed of rice was 12 in. deep, undisturbed, and the airflow continuous. The approximate 3 pounds of water removal lowered each cubic foot of 20% rice to 13% m.c.w.b. For the high air-flow rate of 30 cfm/ft^2 (the broken line curves) the 125°F air dried the 12 in, depth of rice in four hours. The 110°F drying air required 6 hours while the 95°F air needed about 10 hours.

The low air flow rate of 10 cfm/ft^2 (the solid line curves of **Fig. 1**) was only one-third of the high 30 cfm/ft^2 air flow rate but dried the rice in about twice the time. The low air flow rate required only two-thirds as much supplemental heat for an equivalent amount of drying but took twice as much time. The slowest drying operation of 10 cfm/ft^2 with 95°F drying air required about 21 hours. This simulation of a slow dryer indicates that it would be adaptable to a daily schedule—one batch each 24 hours. Drying at 95°F with 30 cfm/ft^2 proceeded at approximately the same rate of moisture removal as drying at 125°F with 10 cfm/ft^2. However, the former resulted in a higher head yield upon milling and thus would appear to be the preferable operating condition.

The average head yield values from milling tests are also shown in **Fig. 1.** The average head yield

Table 1. The effect of drying air temperature on the moisture and temperature gradients at the time the average moisture content of the grain reached 13% w. b.

Treatment	Bottom Layer			Top Layer			Gradient	
	Temp. °F	m.c. %	Head Yield %	Temp. °F	m.c. %	Head Yield %	Temp. °F	m.c. %
30–95–12u *	94	11.9	41**	90	14.7	41	4	2.8
30–110–12u	108	11.2	41	99	15.9	40	9	4.7
30–125–12u	120	9.9	14	100	18.6	41	20	9.0
10–95–12u	90	11.2	44	84	17.5	40	6	6.4
10–110–12u	107	8.9	41	87	19.1	45	10	10.0
10–125–12u	118	8.5	26	88	19.4	42	30	11.0

* 30 is air flow, 95 air temperature, 12 rice depth, and u the treatment (undisturbed)

** In addition to milling samples at the top and bottom, samples were also taken in the center of the bed. Results from center samples were weighted twice as much as those from top and bottom in computing averages. (See **Fig.** 1). Average head yield of room-dried control samples was 42.75 percent.

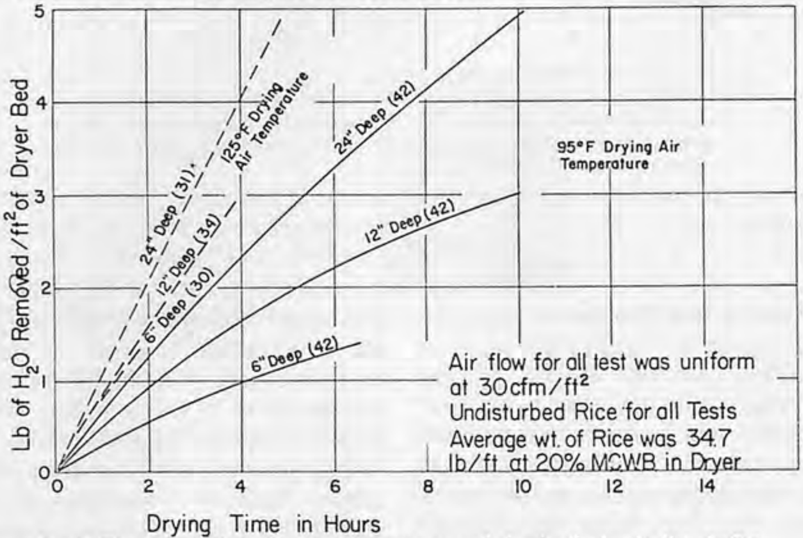

Fig.2. The effect of drying air temperature and depth of rice in the drying bed. ※Numbers in parentheses represents the average head yield in percent after milling. Average head yield for the control (room dried) samples was 42.75 percent.

of room-dried control samples was 42.75 percent indicating that the incoming rice had already been subjected to environmental factors which tended to induce considerable cracking upon milling. (DePadua, 1970) (Arora, 1972). **Fig.** 1 indicates that use, of the 125°F temperature as compared to 110°F and 95°F tends to reduce head yield, and that this effect of a higher temperature is more pronounced at the higher airflow rate. Drying at either 10 or 30 cfm/ft^2 rates at 95°F, or at 110°F at 10 cfm/ft^2 avoided reductions in head yield due to the drying process.

Table 1 shows numerically the effect of drying air temperature on the moisture and temperature gradients within the bed of rice at the termination of the drying period (when an average of 13 m.c.w.b. had been attained). The effect of these factors on head yield obtained in milling tests is also shown. The moisture content and temperature gradients within the 12 in. bed of rice both increased appreciably as drying air temperature increased and as time of drying increased.

The results shown by **Fig.** 2 indicated some improvement of supplemental heat utilization for the deeper beds of rice with the lower drying air temperature of 95°F. The 6 in. deep bed required about 6-1/2 hours for drying, the 12 in. depth 10 hours and the 24 inch depth about 12 hours. For all depths of rice dried at 95°F there was little or no reduction in head yield due to the drying process. The higher drying air temprature of 125°F (the broken line curves of **Fig.** 2) dried the rice to 13% m.c.w.b. in approximately 2, 4, and 6 hours. This indicated some improved efficiency for the 24 in. rice bed depth as there was twice the rice dried as for the 12 in. depth in 50% more time. All of the tests shown on **Fig.** 1 were at the high air flow rate of 30 cfm/ft^2. All of the drying tests at 125°F showed reductions in head yield due to the higher drying temperature. The 6 in. bed depth which the 125°F air dried very rapidly had a low head rice yield of 30%. Also the bottom layer of the 24 in. bed depth became severely overdried.

Undisturbed, continuous-air-flow, fixed-bed drying has an inherent problem of over drying where the drying air is introduced, particularly with the higher air temperatures that tend to lower the moisture content below the desired 13% w.b. (Angladette, 1964). **Fig.** 3 presents the drying results for two alternative treatments; one was periodic stirring, and two, was periodic reversal of air flow by inverting the drying bed. Stirring was done manually every 30 minutes for the 6 in. and 12 in. grain bed depths with the high air flow of 30 cfm/ft^2 at 95°F and 125°F. The curves of **Fig.** 3 show that stirring had little effect on the rate of water removal as compared to undisturbed bed drying. The reversal treatment appreciably decreased the rate of water removal with both the 125°F and the 95°F drying air temperatures. At 125°F, reversal appeared to have a slightly detremental effect on head yield. The stirring treatment at the 125°F drying air temperature caused some reduction in cracked rice as compared to the undisturbed treatment thus, should receive some further consideration when head rice yields are low. Airflow reversal, however, appeared to have no performance advantages and thus represented an unnecessary complication of the drying operation. None of the drying process modifications decreased the cracked rice with the 95°F drying air temperature, because the drying conditions were very near the hygroscopic equilibrium moisture content of 13% w.b. for rough rice. Thus, very little over drying took place.

Air reversal every half hour showed little advantage over the uniform or non-interrupted air flow in so far as head yield or milled rice was concerned. At the 125°F drying air temperature the reversal treatment increased the head rice yield slightly at the bottom, but decreased it at the top. At the 95°F drying air temperature no effect was evident. The reversal treatment tended to lower the moisture content of the top layer with the 125°F drying air temperature and increase it some in the center with the 95°F drying air temperature.

Additional drying treatments were tried at the high air flow rate of 30 cfm/ ft² and the high drying air temperature of 125°F **Fig.** 4 presents the water removal rates graphically. Stirring and tempering had about the same water removal rate as for the traditional undisturbed or uniform air flow. The two treatments involving reversal of air flow were somewhat less efficient in utilizing heat as considerable sensible heat was lost from the grain following each inversion of the drying bed. For the tempering treatment drying air was applied in 30 minute periods separated by off periods of 60 minutes.

Tempering, either as an individual treatment, or in combination with air flow reversal (as well as stirring as an individual treatment) and 125°F drying air temperature showed an increased head yield as compared to the undisturbed treatment. At 125°F the reversal treatment, however, decreased head yield in both the top and bottom layers as compared to the uninterrupted air flow treatment for which head yield was decreased only in the bottom layer. At the 95°F drying air temperature there were no head yield increases with either treatment.

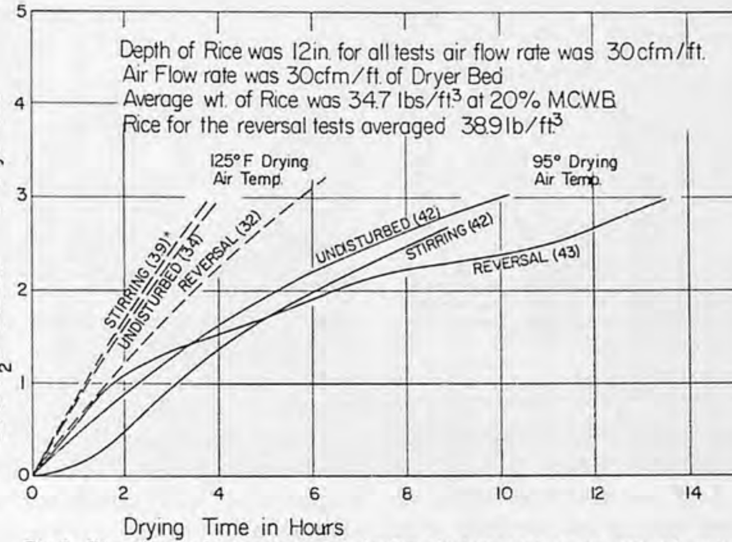

Fig.3. The effect of treatment and drying air temperature on rate of water removal. ※Numbers in parentheses represents the average head yield in percent after milling. Average head yield for the control (room dried) samples was 42.75 percent.

Table 2. The effect of air flow reversal on the head yield at various depths.

Treatment	Bottom		Middle		Top	
	m.c. %	Head Yield** %	m.c. %	Head Yield** %	m.c. %	Head Yield** %
30–125–12u *	9.4	14	13.2	40	18.1	41
30–125–12r	10.0	18	15.0	42	12.8	26
30–95–12u	11.0	41	13.1	42	14.8	41
30–95–12r	12.6	44	16.2	42	14.0	43

* u indicates undisturbed drying, r indicates air reversal every 30 minutes.
** Average head yield of room-dried control samples was 42.75%.

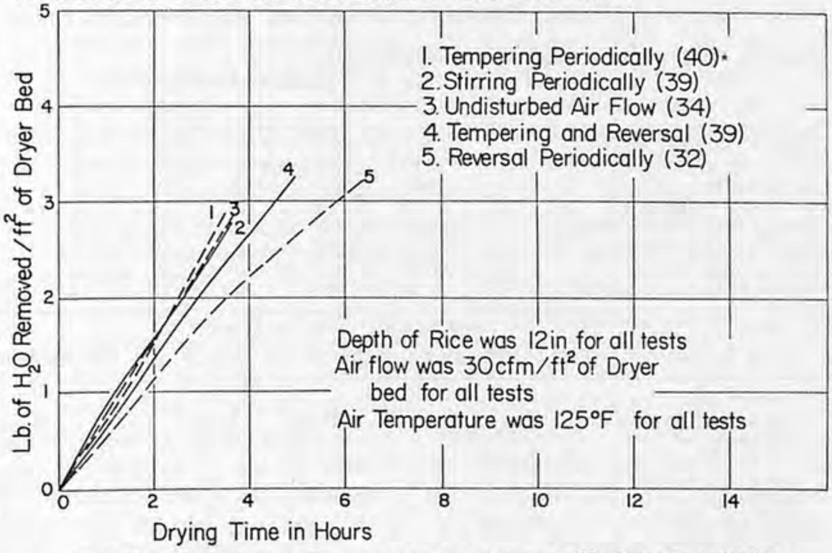

Fig.4. The effect of treatment on rate water removal. ※Numbers in parentheses represents the average head yield in percent after milling. Average head yield for the control (room dried) samples was 42.75 percent.

Table 3. The effect of treatments on the yield of head rice.

Treatment	Head rice yield. Bottom %	 Middle %	 Top %
30–125–12u	14	40	41
30–125–12r	18	42	26
30–125–12t	28	43	44
30–125–12t & r*	34	43	34

* t & r was tempering with drying air on 30 minutes, off 60 minutes, bed was then reversed and drying air turned on for 30 minutes.

Table 4. Static pressures in drying tests*, in. H_2O

Air flow cfm/ft^2	Depth of Moist Grain – in. 6	 12	 24	 12 (densely packed)
10		0.10–0.11		
30	0.20–0.25	0.35–0.40	0.79–0.82	0.49–0.60

* Normal density of packing was approximately 27.8 lb. of dry matter per ft^3. Early Rose is a nonglabrous variety of rice and would tend to require lower static pressures for a given airflow then would glabrous rice varieties. (ASAE Yearbook, 1972).

Available Waste Heat

Tests were made to determine the available waste heat from two small engines that might be utilized for grain drying. The engines were equipped with restrictive throttle plates to limit BMEP to approximately 60 to 70 percent of the maximum possible. This arrangement can enhance engine life significantly in an actual installation in which the engine turns a fan at maximum possible speed continuously for many hours. The 8.3 cubic inch displacement engine with an 18 in. propeller type fan was the more typical size of engine and type of fan for a small flat-bed dryer. The static pressures used in the tests were less than 0.90 inches of water (see **Table. 4**). Thus the propeller fan at low pressure differentials, but with comparatively high air volume output was well suited for the shallow-bed dryer. (Arboleda, 1962).

Performance characteristics of both engine-fan combinations are given in **Table 5.** Date for the 8.3 cu. in. engine with the propeller fan were used in formulating specifications for various drying systems which produced conditions found acceptable from the standpoint of maintaining high head yields of milled rice. The performance of these systems is given in **Table 6.** based on the rice drying characteristics found in this study.

Drying System Selection

Selection of drying systems for developing countries must be based on many factors along with economic efficiency. It is of primary importance that the equipment have a low initial cost and be simple for ease of local production and operation. The low air-flow, flat-bed dryer, for example, can be constructed from local materials and operation of the dryer is not complicated. The use of a low drying air temperature in the range of 95°F eliminates the need for the costly auxillary air heater, which not only uses additional fuel but

Table 5. Performance of Engine-Fan Combinations.

	8.3 cu. in. Displacement Engine with Propeller Fan					23 cu. in. Displacement Engine with Centrifugal Blower				
Static Pressure in. H_2O	0.1	0.25	0.50	0.75	0.90	0.25	1.00	2.00	3.00	4.00
RPM (engine)	2490	2510	2660	2760	2820	2090	2180	2210	2300	2400
Airflow cfm	1960	1325	1052	1030	1016	1975	1848	1694	1406	1030
Air Temp. Increase F°	10	13	14	15	15	17	20	21	23	24
Energy Added to Air, Btu/hr	20,200	17,850	15,200	15,700	15,700	34,600	38,100	36,600	33,300	26,500
Fuel Consumption lb/hr	2.21	2.38	2.65	2.65	2.91	3.44	3.97	4.23	4.50	4.63
Fuel Energy* Btu/hr	40,610	45,700	50,600	50,600	55,600	65,700	76,100	81,200	86,100	88,800
Thermal Efficiency percent	50	39	30	31	28	53	50	45	39	30

* Based on 19,160 Btu/lb, the lower heating value for gasoline.

Table 6. Feasible Drying Systems Based on Use of 8.3 cu. in. Engine with Propeller Fan.

System No.	1	2	3	4	5	6	7	8
Head-Yield Depression	None	None	None	None	None	Slight	Slight	Slight
Air Temp., F°*	90	93.6	95	95	110	110	125 (stirred)	125
Air Rate, cfm/ft^2	10	30	30	10	10	30	30	10
Bed Depth, ft	1	1	2	1	1	1	1	1
Bed Area, ft^2	192	40	34	192	192	40	40	192
Static Pressure, in. H_2O **	0.11	0.40	0.80	0.11	0.40	0.40	0.40	0.11
Fan Airflow Output, cfm **	1920	1180	1010	1920	1920	1180	1180	1920
Auxillary Heat, Btu/hr	0	0	0	10,020	39,600	19,900	38,200	69,200
Heat from Engine, Btu/hr **	20,040	16,500	15,600	20,040	20,040	16,500	16,500	20,040
Total Heat Added, Btu/hr	20,040	16,500	15,600	30,060	59,640	36,400	54,700	89,240
Time to Dry One Batch, hr ***	25.50	11.00	13.50	21.50	14.50	6.75	3.83	10.50
Tons Dried/24 hrs ****	2.85	1.38	1.90	3.38	5.01	2.24	3.94	6.92
Heat Added per Ton Dried, Btu ****	173,000	273,000	190,000	209,000	273,000	361,000	298,000	293,000

* Based on ambient air temperature of 80°F, 75% R.H.
** Based on performance of the 8.3 cu. in. engine and propeller fan.
*** Includes 1/2 hr added to drying time of each batch for loading and emptying.
**** Metric tons of rough rice at 20 percent moisture (w.b.) dried to 13 percent moisture.

complicates the system and it's operation. Drying air temperatures above 110°F tend to overdry and thus, cause grain cracking; so control of the dryer in so far as drying air temperature and time of grain exposure to the heated air is more critical.

Evaluation of alternative drying systems must be based upon the economic conditions of each country. The ability and cost to fabricate and assemble dryer components varies. The cost of operation and value of the dried product must also be considered. The efficiency of the system performance may be based on two main measures; one, the amount of rice dried per unit of time, and two, the amount of heat energy used to dry a given amount of rice. These two measures are enumerated in the bottom two rows of **Table 6** for the eight system variations illustrated. In developing countries energy utilization is a more critical evaluation index than rate of rice throughput.

Systems 1 through 3 require no auxillary heat thus, energy cost in minimal System 1 (10 cfm/ft^2, 1 ft. depth, 90°F drying air temperature) is the best of the three as it's drying rate of 2.85 ton/24 hours is the highest. System 4 show an increase in drying rate over system 1 but must have auxillary heat added to attain the 5°F higher drying air temperature.

When auxillary heat is used, system 5 (10 cfm/ft^2, 1 ft. depth, 110°F drying air temperature) provides a considerably higher throughput than system 1, but economy of energy usage could be a major deterrant. If a slight depression of head yield could be tolerated, system 8 (10 cfm/ft^2, 1 ft, depth, 125°F drying air temperature) provides the highest throughput of rice. System 8 would, however, be slightly inferior to system 5 on the basis of energy use per unit of rice dried.

Conclusions

Evaluation of the drying systems illustrated in **Table 6** for application in developing countries leads to the following conclusions:

1. The energy requirement for grain drying can be minimized with the use of large drying bed area (100 to 200 sq. ft.), low air temperature in the 90s, and low air velocity (10 cfm/f-ft^2) through the bed as compared to the use of higher air temperatures and velocities with smaller drying areas.
2. Use of auxillary heat can increase the throughput of a drying system but it also increases capital investment and operating cost. The efficiency with which purchased energy is used in the drying process decreases with the use of auxillary heat because the drying capacity of the ambient air represents a decreased proportion of the total drying capacity used.
3. The 95°F drying air temperature can be attained under most tropical conditions with waste engine heat thus, no additional capital investment nor operating cost is necessary for the supplemental heating of drying air.
4. The higher drying air temperatures above 110°F tend to cause over-drying and thus lower head yields of milled rice.

REFERENCES

Angladette, A., 1964, Rice Drying Principles and Techniques, FAO, Informal Working Bulletin No. 23.

Arboleda, J. R., A. B. Catambay, and D. B. DePadua, 1962, Shallow Bed Drying of Rough Rice with Heated Air at Different Airflow, Philippine Agriculturalist, Vol. 46, pp. 460-476

Arora, V. K. and S. M. Henderson, 1972, Rice Drying Cracking Versus Thermal and Mechanical Properties, ASAE Paper, St. Joseph, Michigan 49085, No. 72-337.

ASAE Yearbook, 1972, St. Joseph, Michigan 49085

DePadua, D. B., 1970, Basic Principles in Grain Drying and Milling, Rice Production Manual, University of Philippines, College of Agriculture, pp. 247-265.

Esmay, M. L. and C. W. Hall, 1973, Agricultural Mechanization in Developing Countries, Shin-Norinsha Co. Ltd. Tokyo, Japan.

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A Farm and Village Paddy Rice Dryer for Less Developed Countries of the Tropical and Semi-Tropical Regions

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Most new improved rice varieties have shorter growing periods and are non photo-period sensitive; thus are adapted for year around production in tropical areas. The harvest of increased yields may then fall in the rainy season. Traditional sun drying may not be possible nor adequate during the monsoon periods to preserve quality and prepare the paddy rice for favorable marketing, safe storage and necessary transportation. Thus, some type of mechanical rice drying is necessary at the farm or village.

An inherent characteristic of many new improved higher yielding rice varieties, with heavier heads of grain on each stalk, is that the seeds separate from the stalk quite easily. This "shattering" characteristic requires some changes in the traditional patterns of harvesting and handling of the stalk paddy rice to minimize losses. The new, high yielding rice varieties must be harvested as soon as mature and while the field grain moisture content is still high (from 20 to 25 percent, wet basis) in order to minimize field shattering and to allow for the timely preparation of the land for multi-cropping. Once the stalk paddy has been cut it must be handled carefully and threshed immediately, preferably in the field, to minimize shattering losses. The freshly harvested and threshed paddy rice will still have the high (20 to 25 percent) moisture content so must be dried immediately, often times during a rainy season, to prevent spoilage and preserve quality. A simple, lowcost, easily operated dryer for the farm or village is necessary in the less developed areas as inadequate transportation systems limit shipment to centralized drying plants.

Mechanical, heated-air, grain drying technology is highly developed and commonly used in the more developed countries. The cost, size, complexity, and necessary operational preciseness make most of these units impractical for the less developed countries at the farm and village level. Some large dryers are being installed at rice processing and storage centers, but due to distances and inadequate transportation all farmers cannot deliver their rice to these points soon enough during wet weather to prevent spoilage.

There then is a need for some intermediate technology for drying. This paper presents a discussion, as well as functional plants for a small (approximately one metric ton) batch-type, slow dryer that uses waste heat from the fan engine to enhance the rice drying process.

Drying Principles

Moisture is removed from grain kernels by evaporation. Evaporation takes place mainly on the kernel surface, thus a diffusion movement of water to the surface is involved. Heat energy must be supplied to support the evaporation and diffusion processes. The heat may be transmitted to the grain kernels by convection, conduction, or radiation (Hall, 1957, and Agrawal et al, 1968).

The application of heat to the grain kernel surface and the resulting evaporation induces both temperature and moisture *gradients* within the kernel. The extent and magnitude of these gradients vary with the mode and rate of heat supplied and the temperature differences within the kernel. Stress chechs and cracks are induced in the kernels proportional to the magnitude of the gradient differentials. Differential gradients can also be created by the reverse process of cooling and desorption (loss) of moisture (Kunze and Hall, 1967).

The grain seed embryo is a living organism surrounded by straches and protein *hygroscopic* materials that require controlled conditions for the preservation of the original food quality. The embryo metabolic process (respiration) is stimulated by increased temperature and moisture conditions. Nourishment is drawn from the endosperm nutrients, thus diminishing the valuable starch and protein levels. Heat and moistare are produced by the metabolic process and an accelerating chain reaction is created. The higher temperature and moisture conditions are also stimulants for increased activity of microorganisms and insetcs. These organisms can destroy the value of high moisture rice in three days under high temperature and humidity conditions.

The *quality* of polished rice is mainly determined by the proportion of unbroken or "head" rice present after processing. Some grain kernels may be broken by the physical impact and abrasion of the hulling and polishing machines, particularly if the equipment is worn or improperly adjusted. The major portion of broken grains are caused by normal processing stresses interacting with the checks and cracks induced previously by improper drying.

Natural drying, as well as rapid uncontrolled drying at high temperatures can create stress checks and cracks. Natural sun drying of stalk paddy standing in the field or of grain paddy on a drying floor will, over a period of days, cause wetting and drying to occur due to exposure to varying temperatures and periods of high humidity during nights and rainy periods. Drying and wetting cycles induce many stress checks and cracks.

Two basic types of mechanical *drying systems* have been developed. *One* is a *slow-drying* operation which controls the temperature of the drying air at the hygroscopic temperature equivalent of the grain moisture content (The drying air temperature should normally not be more than 15° above atmospheric air temperature). See **Fig. 1** for the equivalent temperature and humidity levels for various moisture contents of common grains.

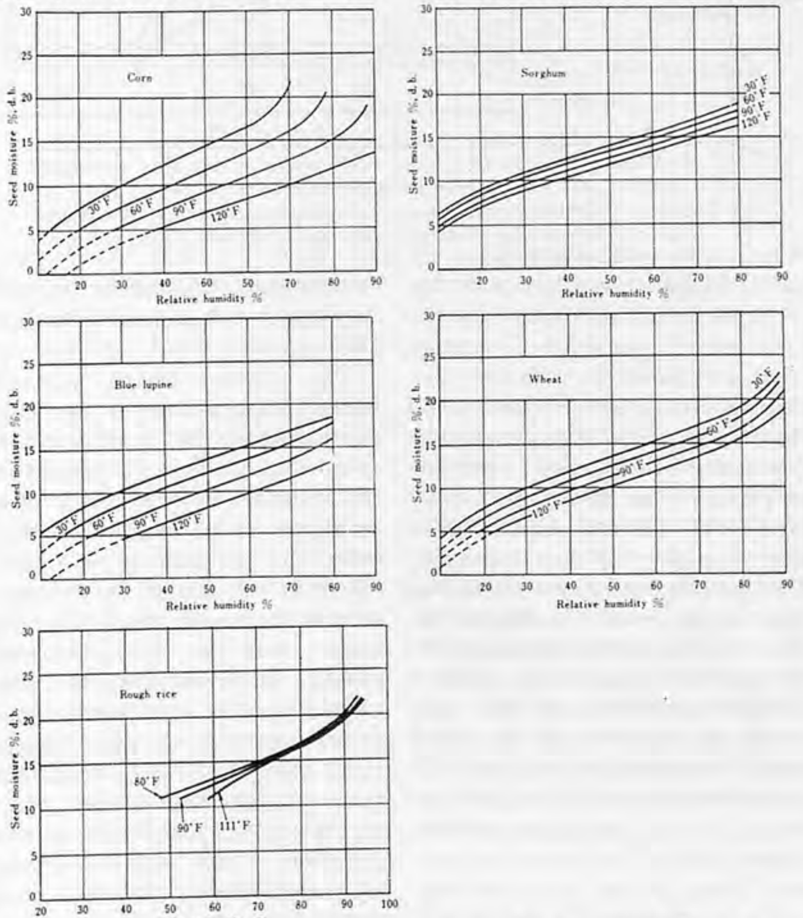
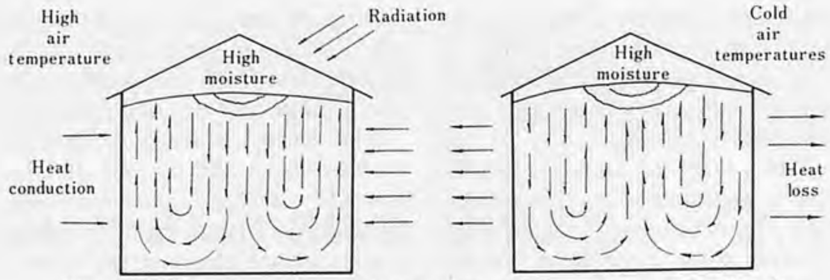


Fig 1. Hygroscopic equilibriums of grains. Source: Rough rice only. Hogan, J. T. and karon, M. L., Hygroscopic equilibrium of rough rice at elevated temperatures. Agr. and food chemistry, Vol. 3: No. 10, 1955, 855-860. Taken from ASAE Yearbook, 1972.



Direction and pattern of convection currents and thus moisture migration in stored grain caused by warm (on the left) and cold (on the right) climatic conditions.

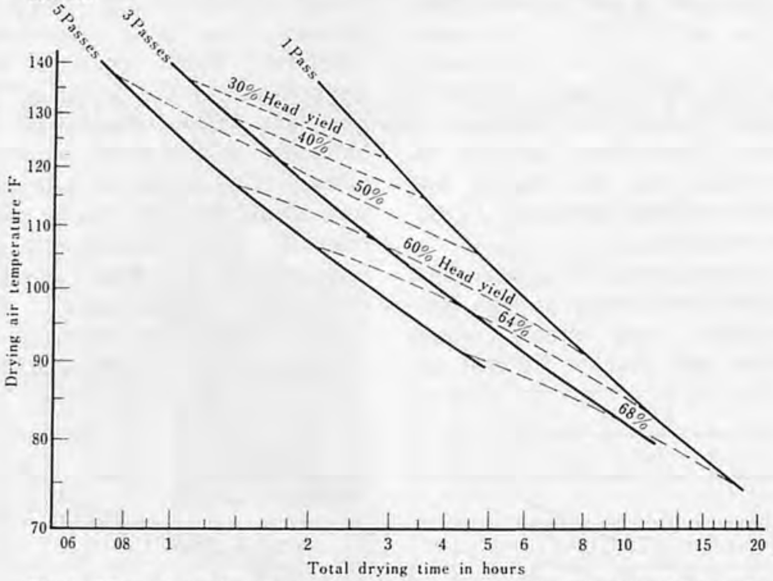


Fig 2. Effect of number of passes and of air temperature on drying time and head yield. Broken lines join points of equal head yields. (Rice was dried in trays holding 2-inch beds of rice.)

For example, if rough rice is to be dried to 14 percent, the equivalent temperature and relative humidity should be approximately 90° F and 65% (Barr, 1955). *Two,* is a *fast drying* operation which also controls temperature, but at a higher level (up to 140° F), and drying time more precisely for short periods. The high temperature exposure time for the grain is adjusted to allow moisture content reduction of not more than 2 to 3 percentage points during one exposure to the hot air. A "tempering" period of a few hours is then provided to allow for equalization of gradients and to relieve internal stresses. Successive drying passes are provided with intermittent "tempering" periods until the grain is at the desired moisture content. **Fig. 2** shows a relationship between air temperature, the number of drying passes and percent of broken kernels.

The slower drying process, lower temperatures, is generally characterized by a fairly low volume of air flow as related to the volume of grain. Air flow rates are in the range of 1 to 5 cubic feet per minute per bushel of grain. (A bushel is approximately 25 percent more than one cubic foot so this converts roughly to from 1 to 6 cubic meters of air per minute per cubic meter of grain). Drying takes place in the grain mass in a fairly limited zone called a "drying front" which moves in the direction of air flow as drying progresses. **Fig. 3** illustrates how drying takes place in the slow drying system.

The second and more common (in the more developed countries) temper-drying process is faster and is characterized by a high volume of air flow to volume of grain. Air flow would normally be above 25 cubic feet per minute per bushel (approximately 25 to 30 cubic meters per cubic meter of grain).

Economic Returns

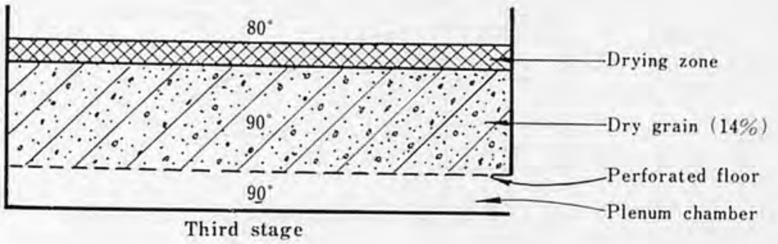
mechanical grain drying, like other types of production and processing mechanization, is justified mainly by the maintenance of *product quality* (prevention of losses). Quality cannot be preserved during storage unless the grain is first dried to from 13 to 14 percent moisture content (wet basis). Storage losses have been documented as high as 50 percent of the stored crop with average storage losses in many developing countries from 5 to 10 percent (Ojha, 1968). Studiesin India indicate that the sale price of rice may be reduced by one-half during the normal "glut" at harvest. Thus, economic returns from storing beyond the low price period and through the prevention of storage losses can be very high.

Proper drying carried out after havesting within the moisture content range of from 21 to 24 percent, as indicated by **Fig. 4** minimizes the cracking of kernels (Bhole, et al, 1970). Rice, unlike most other food grains is eaten as a whole grain. Thus, the proportion of unbroken kernels (head rice) is economically important for marketing. For home consumption, particularly during times of food shortage, broken rice kernels are quite acceptable. There are, however, some actual losses from broken rice as the fine material disappears.

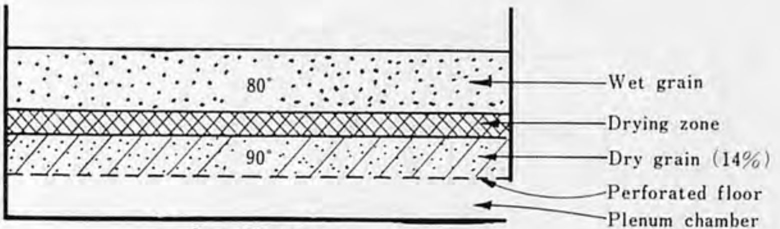
Drying Systems

The use of the *drying floor* for sun drying has been traditional for generations. The rice is spread in a thin layer and stirred frequently. Drying takes a few days depending on the sun intensity. Rain showers and night dew can cause rewetting if the rice is not protected properly. Rodents and birds cause some loss and contamination in most cases. Operating cost is low as only floor space and labor are required. (About one-fortieth of an acre of drying. Floor is required for each ton of rice). The cost and availability of labor varies from country to country. Drying space and labor can also become scarce as yields and production intensity increase. Labor demand is seasonal thus temporary shortages occur. Multicropping may also cause the harvest period to coincide with the rainy season which may make sun drying impossible. Various versions of solar drying have been developed but all, unfortunately, depend upon the sun shining at the time of drying. Sun drying efficiency can be increased significantly with the use of plastics or glass and forced air, but the costs also increase (Bailey, et al, 1965).

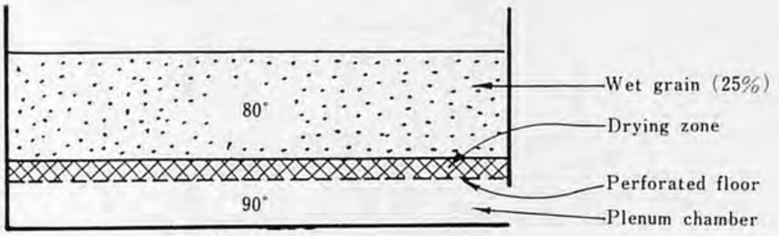
Fire heated drying platforms have been developed. Continuous stirring is necessary to prevent over heating and scorching. Temperature control of the metal platform is impossible with an open fire below as a heat source. Over drying ofen results which prevents seed germination and affects taste for consumption purposes. The drying platform would be classified mainly as a *conduction dryer*. The International Rice Research Institute is doing some developmental work on a very high temperature (over 200°C) conduction dryer. Sand is used as the heating medium. The high moisture (25 to 30 percent) rice is essentially cooked or parboiled during this quich (15 to 20 seconds) drying process; thus, changing the flavor. The sand conduction dryer remains in the experimental stage for now as there are problems of high energy requirements, materials handling and machine costs (Khan, et al. 1971).



Third stage



Second stage



First stage

Fig 3. Formation and movement of the drying zone in the fixed-bed dryer over a period of 24 hours with a comparatively low air flow rate and a low drying air temperature.

Hot air *convection* grain dryers are the most common mechanical drying systems. There are two basic systems; the batch (slow) dryer and the continuous flow (fast) dryer. The small (in the range of one metric ton of rice) *batch dryers* are the simplest and least costly of the two types. Over one million small batch dryers have been introduced on individual Japanese farms averaging one hectare in size. The drying air is commonly heated with a fuel oil burner and forced through the fixed bed of grain by an electric motor powered fan. In non-electrified regiongs, fans must be powered by small internal combustion engines. Air heating must be limited to from 10 to 15° above the climatic air temperature or appreciable over drying and kernel cracking will result.

Continuous flow dryers are adaptable to the larger capacity drying requirements of processing centers. High air temperatures (140° F) are used and control is critical. With proper management satisfactory results can be obtained with the large dryers and continuous utilization can make them economical. Since all farmers cannot be located near large drying centers, the continuous flow dryers do not solve all the farmers immediate drying problems during the wet harvest seasons.

The Batch-Type Dryer

Some adaptation of the small batch-type dryer has the greatest

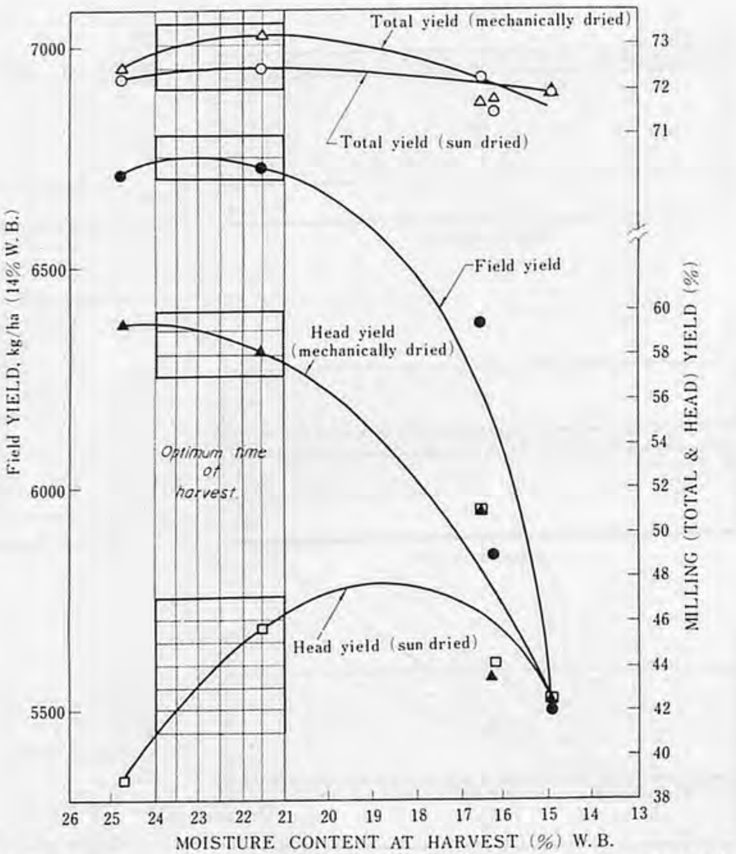


Fig 4. Effect of moisture content at harvest on field yield and milling yield of IR-8. paddy variety.

potential for solving the grain drying problems at the farm and village level in some less developed countries. The drying system can be made small and quite inexpensive for decentralization to the villages where they might be purchased and used cooperatively or by an individual. Operation of the unit is quite simple.

The remainder of this paper describes in detail a small batch-type dryer that utilizes waste heat from the fan engine for heating the drying air. No additional air heating unit is required, thus saving fuel and simplifying the drying system. A small (approximately 2-1/2 horse-power) internal combustion engine is required to operate the fan to force the drying air through the grain.

The constraints placed upon the development of this batch-type dryer are as follows:

1. Light and simple for easy movement to and operation in the villages.
2. Local construction for all parts of the dryer except the engine.
3. Minimum skill requirement for operation beyond that for a small engine.

Specifications for the dryer are as follows:

1. A 2-1/2 horsepower internal combustion gasoline engine for the fan power.
2. V-belt power transmission to the fan.
3. A simple fan capable of delivering from 2000 to 3000 cfm of air against a static pressure of 1/2 inch of water.
4. Engine shrouding designed to direct incoming air by the engine for heating from 5 to 10° F.
5. Simple heat exchanger used to reclaim exhaust heat.
6. Exhaust fumes should not be forced through rice.
7. Depth of rice in the drying bin may be up to a maximum of two feet.
8. Approximately a one day (24-hr) drying period requirement under typical tropical weather conditions.

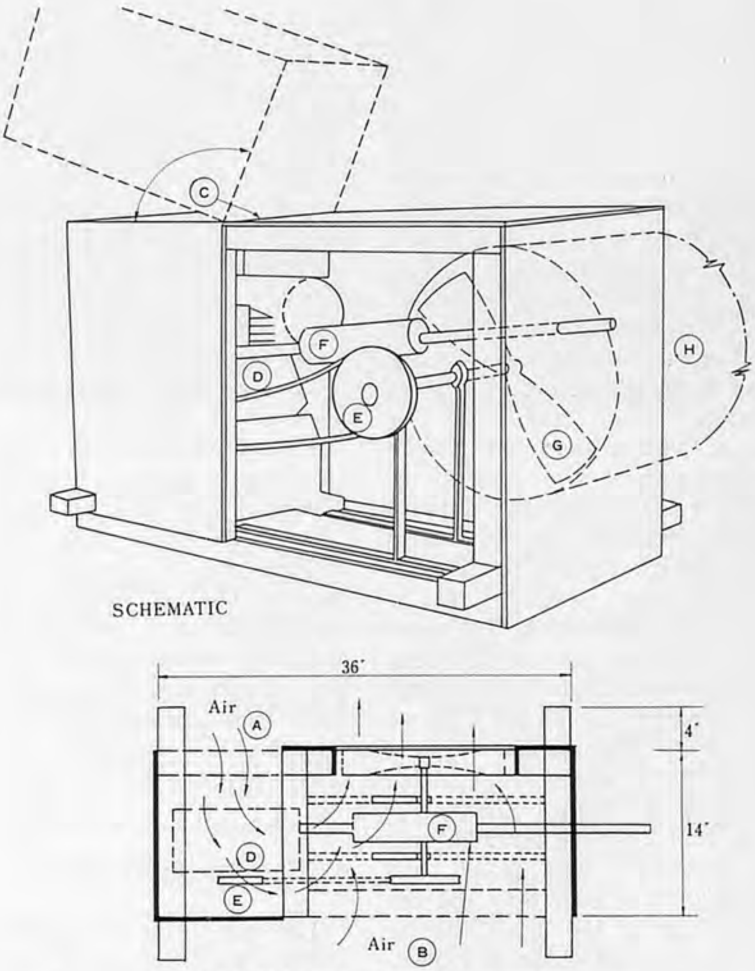
Drying Unit Construction

Engine procurement is necessarily the first step. The engine mount and housing must be designed according to the dimensions of the engine. **Fig. 5** shows the engine-fan-power transmission system as a total unit. The engine housing must allow for a minimum air clearance of two inches on all sides. The housing assembly must be removable to allow access for engine starting and maintenance. The engine housing can be hinged at the top to provide this access. The engine housing must also be open on the opposite end from the fan to provide air flow across the engine. The fan front is unobstructed so that most of the air flows directly into the fan with minimum turbulence. (See **Fig. 5** for air flow diagram). All small air cooled gasoline engines contain an internal cooling system. The engine placement and housing must cause the air to flow across the engine cooling system and then into the fan. Some engines must be located somewhat differently than the one shown in this paper, but simple modifications will allow the use of most any small engine.

A gas tight exhaust muffler is located directly in the air stream for maximum heat exchange. The muffler can best be mounted horizontally from the engine and through the far side of the fan shroud. The shroud opening for the exhaust pipe should be oversized to allow some adjustment of engine tilt for maintaining proper belt tension. Since considerable vibration is inherent in a two-cycle engine the exhaust muffler requires an additional brace back to the engine. A muffler designed for a 20 to 30 hp engine will provide additional heat transfer surface. (Approximately 6 inches in diameter and 16 inches long).

The engine mount is designed to anchor the engine on a single long bolt. Thus, the engine may be easily removed by releasing the tension spring and removing the bolt. The spring adjusts automatically during operation to provide optimum belt tension. The engine may be easily disconnected and shifted to other equipment when the dryer is not in use.

The fan shroud is constructed from sheet metal as smoothly and precisely as possible. The shroud is eight inches deep with a maximum of 1/2 inch clearance beyond the fan blade tips. The fan blades should be centered in the 8-inch shroud. The transition air duct to the grain drying bin is fastened to the outlet edge of the fan shroud.



SCHEMATIC

Fig 5. Floor plan of engine dryer unit.

Fan Selection

Preliminary tests were made with a *centrifugal blower* that was designed to deliver about 2100 cfm of air against a static pressure of 4 inches of water. It could deliver a maximum of 4350 cfm of air at 1/2 inch static pressure but required 5-1/2 hp. (A 10 hp engine was required for continuous operation). The blower cost was over $500.00 and the engine near $300.00. The combined weight of fan and engine was 350 pounds. The unit was too heavy expensive. Smaller blower units were considered but price weight were always prohibitive.

Axial flow fan blades were eventually considered. Such fans are quite efficient for low static pressure air deliveries and notably inefficient for high static pressure differences (above 1/2 inch of static pressure). The propeller-type fan blades are simple, light, easily constructed and thus low cost. An 18-inch propeller fan was eventually selected from a wholesale catalog. It was Dayton 4C177 type fan rated at 4500 cfm at 1/2 inch static pressure difference with a theoretical air power requirement of 0.33 hp. The fan blade assembly without bearings or support cost less than $5.00.

The fan blade assembly as mounted in the "shopmade" shroud at MSU and powered with a 2-1/2 hp gas engine delivered 2375 cfm against a 1/2 inch static pressure. The difference between this delivery rate and the 4500 cfm rated output was due to less than ideal ducting, shrouding and inlet design. The 2375 cfm output balanced well with the engine heat available as a 7-1/2° F temperature increase was obtained. A higher volume output would lower the temperature increase and make the dryer less efficient in humid climates. The sacrifice of efficiency was considered acceptable in order that the fan assembly might be constructed by local artisons. The propeller type fan is non-overloading in that less power is needed as it approaches full static pressure load.

Fan Assembly

Sealed ball or roller bearings are utilized on most modern machinery because of their low maintenance and long life. A low cost nylon journal bearing was first tested for the fan mount. This consisted of a section of drilled nylon for the bearing assembly. The comparatively low operating rpm (not over 1800) and low bearing loading allowed nylon to be an acceptable alternative to ball or roller bearings. The nylon bearing is simple to fasten to a wooden retainer with a pin and has an acceptable coefficient of friction when used with a steel shaft, of 0.15 to 0.40 with no lubrication and 0.02 to 0.11 with lubrication. A standard bronze-steel journal has a coefficient of friction of 0.34 dry and 0.173 lubricated. Nylon for bearing construction can be drilled with a sharp bit and installed without machining. If desired, it can be machined to fairly close tolerances. The nylon bearing does not require complex oil passages for pressure oil or grease cup lubrication. The nylon does, however, have a high temperature limitation. In this bearing assembly the fan air is drawn across the bearing and keeps it below 110° F, which is well within the design temperature limits.

A second bearing assembly was put together with sealed ball bearings. The cost may run ten times that of the nylon bearing but less trouble would be expected in the long run for drying units operated in the villages of developing countries. The radial loading applied by the power unit and the thrust component of the fan are well below the maximum ratings for commercially available ball bearing assemblies and thus a long operating life is expected. The ball bearings are self aligning so greater tolerances are permissable.

Power Unit

Conventional axial-flow-fan crop dryers use electric motors with direct drive power transmission. For the remote villages of developing countries internal energy power sources must be used. The conventional small gasoline enige proposed for this dryer is being introduced with other types of agricultural mechanization and so does not require new operational skills. The physcial dimensions of even a small 2-1/2 hp gasoline engine, as related to the 18" diameter fan airstream, dictates that it be placed outside of the main airstream in order to minimize turbulence. Also, a high velocity air flow across the engine might keep it cooled below the design operating temperature.

The gasoline engine selected, operated at 3500 rpm while the fan was designed for an optimum 1750 rpm. The fan pulley (5" in diameter) was selected twice as large as the engine pulley (2-1/2" in diameter) to provide this reduction. The belt provides all of the cushion shock and vibration dampener needed for this assembly. Alignment is not critical and fairly wide tension variations are tolerable as minimum power loads are transmitted.

Air Duct Desing Factors

The inlet to the fan greatly influences the efficiency of air flow through the system. The flanged entrance, used for these preliminary tests, has a resistance equal to 5 feet of equal diameter ducting. The flange, however, is easier to construct and better than the unflanged pipe entrance which has a loss equivalent to 90 feet of duct. The smoothest type of well rounded entrance flange could reduce this loss to an equivalent of less than 5 feet of duct, but would be expensive to fabricate.

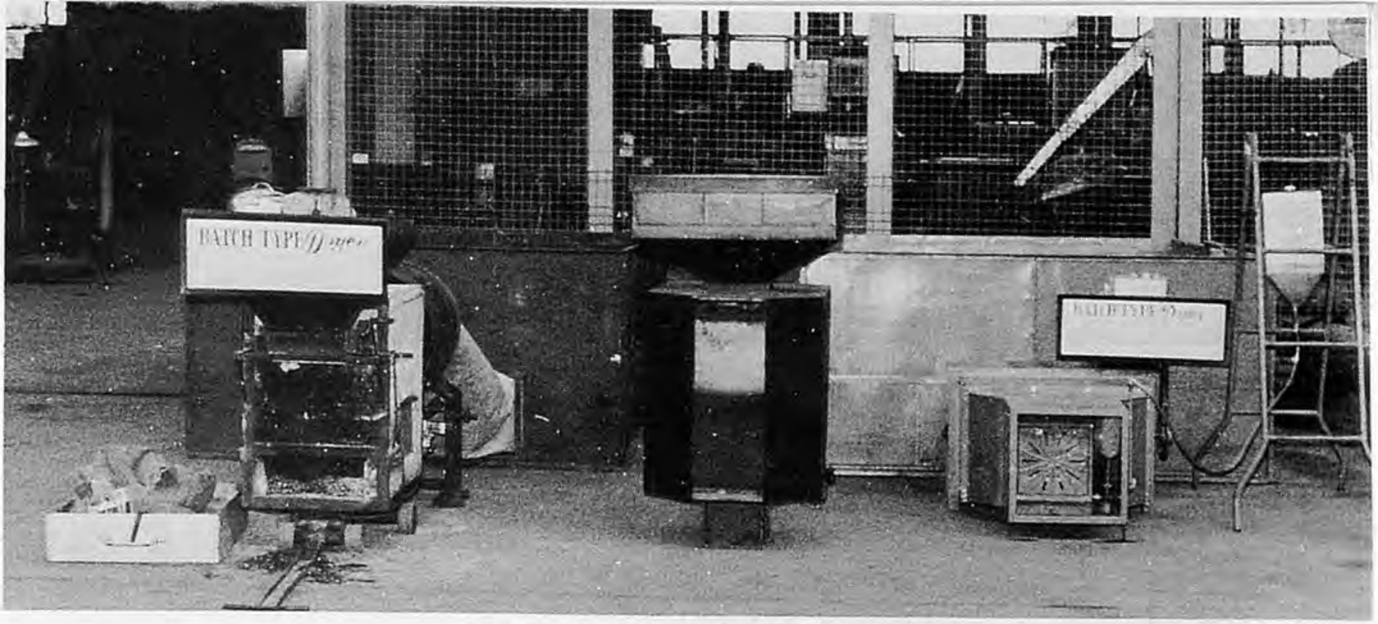
A plastic duct was used to extend from the fan to the plenum chamber below the drying bin. The plastic duct functions well as a vibration damper and is easily attached at either end without alignment being critical. This transition duct from fan to drying bin must, however, be as short as possible to minimize heat loss. The 18-inch diameter duct at the fan entrance should have an expansion taper of from 10 to 12 degrees to minimize the pressure drop in the air stream.

Air Heating Tests

The power and fan assembly delivered 2375 cfm of air at a static pressure difference of 1/2 inch of water measured at the plenum chamber. With the engine shrouded to draw part of the air across the 2-1/2 hp engine, the air stream was heated 7-1/2°F with the exhaust gases released into the air stream. Although the exposure of paddy rice to exhaust gases is not recommended the initial test was made this way for comparison purposes. The sensible heat increase of the drying air was 1.29 btu per pound of air for a total heat energy pick up of 13,200 btu per hour. The gasoline engine consumes about one quart of fuel per hour with a theoretical heat content of 30,00 btu.

The power and fan assembly was next tested with a muffler type heat exchanger on the exhaust pipe to vent the gases outside of the air stream. The air stream temperature increase was reduced to 6° F as compared to 7-1/2° F before, but the venting of combustion water vapor to the outside allowed the wet-bulb temperature to remain constant and the net heat pick up was 1.47 btu/pound of air for an effective total of 15,063 btu/hour. This indicates an increase of heat absorption by venting exhaust gases to the outside and provides a pick up of one-half of the theoretical heat content of the gasoline fuel used by the engine.

If unheated air was used in an attempt to dry paddy rice under climatic conditions of 90% relative humidity and 90° F, the equilibrium moisture content would allow a moisture reduction to only 19.1% wet basis. The additional engine heat added by this drying unit makes it possible to dry the paddy to a storable



Batch type dryer developed by IRRI

14% wet basis. The 19% paddy would not keep many days without appreciable damage from molds.

Functional Dryer Design

A 24-hour drying period would be desirable under tropical weather conditions and with high moisture paddy rice. The fan and power unit assembly will deliver near 2400 cfm against a static pressure difference of 1/2 inch of water. This would be approximately 24 cfm per sq ft of bin floor area through a one foot depth of paddy rice for a bin floor approximately 10 ft x 10 ft in size. This is roughly 1-1/2 metric tons of paddy rice.

The operating cost of the drying unit should amount to only a small fraction of a penny (0.25¢) per pound of paddy rice dried. Operating costs must be determined in the country of operation as fuel and labor costs vary. The unit should cost less than $100.00 to construct as it is planned to use mostly local material.

If the drying front moves up through the grain in appreciably less than a day, the depth of paddy rice may be increased for subsequent days as long as the climate and wet paddy rice continue to be fairly constant. The progress of the drying front can be easily checked by slowly pushing a blunt stick down into the paddy rice. When it enters the dried portion of grain it moves much easier.

Farmers should become accustomed to the fact that paddy rice shrinks in volume and weight when it is dried. The only loss though is the undesirable water.

Construction of the Drying Unit

While the construction of the drying unit is straight forward, the airflow rates and temperature rise through the unit are dependent upon careful attention to design details. The unit, if properly constructed, will not be influenced critically by normal variation between operators. During the course of the testing at Michigan State University refinements in design and construction increased the airflow rate from 2400 cfm to 3100 cfm with the same static pressure heads and dryer components. Thus the first test model should be constructed carefully and evaluated under actual operating conditions.

REFERENCES

Agrawal, K. K., and Tal Radhey, 1968, Principles and Practices of Rice Drying, Department of Agricultural Engineering, Indian Institute of Technology, Kharagpur, India.

Bailey, P. H., and W. F. Williamson, 1965, Some Experiments on Drying Grain by Solar Radiation, Journal of Agricultural Engineering Research, Vol. X, No. 3, pp. 194-5.

Barr, H. T., et al, 1955, Recommendations for Bin Drying and Storage of Rough Rice, Agricultural Experiment Station, Louisiana State University.

Bhole, H. G., Satish Bal, V. V. Rama Rao, and J. E. Wimberly, 1970, Paddy Harvesting and Drying Studies at Thanjavur, District of Ramil Nadus. Paper presented at the annual meeting of the Indian Society of Agricultural Engineers at Punjab Agricultural University, Ludhiana, India.

Hall, Carl W., 1957, Drying Farm Crops, Edwards Brothers, Ind. Ann Arbor, Michigan.

Khan, Amir U., F. E. Nichols and Bart Duff, 1971, Agricultural Equipment Development Research for Tropical Rice Cultivation, Agricultural Engineering Department, International Rice Research Institute, Los Banos, Luguna, Philippines, Semi-Annual Progress Report No. 13.

Kunze, O. R., C. W.Hall, 1967, Moisture Adsorption Characteristics of Brown Rice, ASAE Transactions 19 (4): 448-450, 453.

Ojha, T. P. and Husain Ashfag, 1968, Grain Drying and Dryers, Department of Agricultural Engineering, Indian Institute of Technology, Kharagpur, India.

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News from India

Selective Mechanization of Farming Suggested

By
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Mr. Nathu Ram Mirdha, Chairman of the National Commission on Agriculture, today, called for "Selective mechanization" of agriculture consistent with the employment situation in different parts of the country.

Mr. Mirdha, who was inaugurating a three-day convention of the Indian Society of Agricultural Engineers at the Tamil Nadu Agricultural University Campus here, said while the profitability from mechanization under intensive agriculture had been establised beyond doubt, the scope and potentiality for mechanization of agriculture should be studied in depth.

He said they must also bear in mind the impact of improved technology on rural employment in irrigated as well as rainfed areas.

Mr. Mirdha pleaded for research on the problem of reclamation of desert land in Rajasthan and Gujarat and development of implements to remove wild grass and weeds which often affected crops.

He wanted horticulture operations to be mechanized so that fruit crops might be processed for quick sale in the internal and external markets.

Mr. Mirdha called for well-co-ordinated research and development programmes which would not only make available useful and reliable data on the economics of the use of machinery and implements, but would wimultaneously provide effective extension service to farmers.

He pointed out that mechanization had taken place in the country without an adequate infrastructure to provide maintenance and repair facilities for the farmers.

Mr. Mirdha praised the Tamil Nadu Government for itsachievements in the field of agricultural engineering and for being the first state in the country to have a full-fledged independent department of agricultural engineering.

Dr.J.S. Patel, President of the Indian Society of Agricultural Engineers in his presidential address said in the 70s they should concentrate on promoting selective mechanization and better water management. Selective mechanization would help in increasing production and improving labour efficiency.

He said the country had made good progress in manufacturing pumps, tractores and other farm machinery, but agricultural credit, which at one time stimulated sales of agricultural machinery, is now sluggish partey because of recent agrarian measures.

State Co-operation Minister Si.Pa.Aditanar, who released a souvenir, said in Tamil Nadu only 10 percent of three croreacres of cultivated land had assured irrigation and they had to tap underground water to raise the economic status of farmers in the State.

He said if the agricultural engineer also acted as geologist and agronomist, it would help co-operative banks to process quickly applications for loans to sink tubewells.

He did not agree with Dr.Patel that distribution of agricultural credit had become sluggish and said their experience in Tamil Nadu was that though Rs.44.9 crores was available for distribution as longterm loans for purchase of machinery and sinking wells, the response had been poor.

Referring to the State Government's proposal to appoint one engineer for each of the 375

Panchayat Unions in the State. Mr.Aditanar said they had received only 20 applications from engineers for 200 posts. This showed that the alleged unemploymet among engineers was a bogey.

The Minister said irrigation co-operatives for small farmers would go a long way in promoting mechanization of agriculture. The scheme had a measure of excess in Tamil Nadu, and other states were showing keen interest in the scheme—

Mr.A. Sivasailam, Chairman of the Tractor and Farm equipment Ltd., wondered why large-scale farming on a corporate basis should not be encouraged to achieve higher production and productivity.

He said while the have-nots had to be protected and aided by Government in a socialist economy, "it may not be right or even truly socialistic to ignore any added advantages to society that can be brought about by supplementing such efforts in encouraging a parallel, yet strictly controlled, large-scale farming operations".

Dr. G. Rangaswami, Vice-Chancellor of the Agriculture University, said the scope of agricultural engineering had now been widened to include all aspects of utilization of soil, water and sunlight and processing and marketing of product besides development of machinery and tools.

Extracted from "The Indian Express" dated 17-1-73. ■ ■

Prospects of Farm Equipment Industry

By

B. K. S. Jain

Vice-president of ISAE,
Chairman of ISAE Committee
on Agricultural Engineering
Industry, India

On the eve of the annual convention of the Indian Society of Agricultural Engineers, it is an appropriate occasion to review the state of the farm equipment industry in the country.

During the year 1972, there has been some declaration in the pace of farm mechanization. Some of the reasons for the current situation are drought conditions in several States, uncertainties created by proposals for imposition of ceilings on land-holdings difficulties in lending funds due to improper land records, bad recoveries and absence of under-writing the risk of default and increase in prices of farm equipment inputs, in particular tractors, due to higher taxes and levies. Mechanization to us means increase of power availability, rise in cropping intensity and improvement in farm productivity. Since we must support the set-in trend for improving the farm productivity, all possible efforts should be made to correct the present situation and re-accelerate the pace of mechanization. We have no control on drought, but other factors do require corrective action. It is important that former receives remunerative prices for his produce, only then he will be able to invest in farm equipment inputs, Rising costs of agricultural inputs are resulting in increased pressure on profitability of farm operations.

Farm Tractors

The tractor industry in the country has just commenced its second decade. It has given a good account of its performance during the last 11 years (**Table 1**). Production of over a lakh of tractors during the last 11 years may not be spectacular, but appreciating the difficulties faced by the industry in its first decade, the progress is noteworthy. The local content achieved on the indigenous tractor varies from 50 per cent. to 90 per cent. A sound foundation has been laid and the industry has now geared itself to meet the country's requirements and to prepare itself for opportunities in the export market.

Current numbers of tractors are estimated around 2 lakh units. The growth in tractor population for the first 25 years of independent India in shown in **Table 2**. By the end of the Fifth Plan Period (1978-79), the population may rise to 5 lakh units. Estimates of current power availability on our farms are 0.4 HP per hectare which is expected

Table 1: Tractor availability 1961–72

Year	Indigenous production	Wheel tractor imports	Total Qty. (2 + 3)
1	2	3	4
1961–62	880	2,997	3,887
1962–63	1,414	2,616	4,030
1963–64	1,983	2,346	4,329
1964–65	4,323	2,323	6,646
1965–66	5,714	1,898	7,703
1966–67	8,816	2,591	11,407
1967–68	11,394	4,038	15,432
1968–69	15,437	12,397	27,834
1969–70	17,101	12,701	29,802
1970–71	19,535	16,465*	33,215
1971–72	16,750	16,679	36,214
Total	103,347	77,142	180,489
Percentage	57	43	100

* Estimates

Table 2: Tractor population, 1946–72.

Year	No. of Tractors	Rise since last census	Increase % in 5 years	Annual population rice %
1946	4,524	–	–	–
1951	8,635	4,111	91	18
1956	21,005	12,370	143	29
1961	31,016	10,011	48	10
1966	54,012	22,996	74	15
1971	143,000	88,988	128	26
1972	173,000	30,000	–	21

to rise to 1.7 HP per hectare by 1978-79, against an optimum figure of 1HP per hectare.

The situation suggests that we may be reaching a stage where annual tractor demand may level off. There is general agreement among various agencies on the current estimates of tractor demand at 30,000 to 35,000 units a year. Disagreement, however, continues on the future pattern of demand, say by 1978-79. Industry's estimates are that demand may rise only to a level varying from 40,000 to 60,000 units. An ISAE study shows that the demand may level off at 60,000 units. The National Council of Applied Economic Research estimates the demand to rise to 80,000 by 1979-80 and to 135,000 units by 1983-84. Current situation does not support the optimism of the NCAER.

In fact, there is no waiting list for tractors now. In one or two cases, there may be some backlog of unexecuted orders due to a long spell during which there was insufficient production in the concerned units. The indigeneous industry is now capable of meeting the demand and, therefore, imports of tractors should be completely banned.

Table 3: Tractor units in production

Sl. No.	Unit	H.P.	Current list price (as fixed by Govt. of India)	Annual licensed capacity (Nos)
			Rs.	
1.	Eicher	26.5	25,200	2,000
2.	Escorts	34.5	25,200	16,000
3.	Escorts Tractors (Ford)	46	36,495	6,000
4.	HMT (Zetor)	25	21,500	12,000
5.	Hindustan	35 50	24,100 32,900	7,000
6.	International	35 44	26,300 29,600	10,000
7.	Massey Fergusion	35	26,300	7,000
	Total			60,000

Estimates of break-up of tractor demand by size by 1978-79 are:

Tractor size (HP)	Estimates of demand—%
Upto 25	15—20
26 to 40	50—60
41 and above	25—30

Seven units are now in production as per **Table 3.**

The situation on the industrial licensing of the units is shown in **Table 4.**

It is obvious that the industry has been over-licensed. It is advisable to render all possible assistance to the existing units in increasing the production according to requirements.

Some important problems of the industry relate to finance, availability of steel raw materials and ancillaries, over-licensing of the prouction capacity, continuous threat of tractor imports and logistics including training, insurance, safety, fuels and heavy incidence of taxes and levies. Some important items currently in short supply include pistons, rings and liners, special castings, steering gear and tyres. Taxes and levies account for as much as Rs. 8400 on a 35 HP tractor cost of Rs. 29,000-29 per cent. of the total cost of a tractor to the farmer; of this 11.5 per cent. is excise, 7.5 per cent. import duty and 10 per cent. sales tax.

The ISAE and the Panel on Tractors of the Development Council have made several useful

Table 4

Tractor Size (H.P.)	Annual Production Licensed capacity (Nos.)	Letter of intent capacity (Nos.)
Upto 25	38,500	–
26 to 35	56,000	10,000
36 to 50	44,500	15,000
Above 50	8,000	16,000
Total	147,000 + = 188,000	41,000
No. of units	17 + = 22	5 (+1 Extn.)

Table 5: Availability of power-tillers, 1965–72

Year	Indigenous production	Imports under Yen Credit	Total availability (2 + 3)
1	2	3	4
1965	266	412	678
1966	261	611	872
1967	264	567	831
1968	228	1291	1519
1969	219	2226	2445
1970	361	2900	3261
1971	146	–	146
1972 (up to Nov.)	152	–	152
Total	1897	8007	9894
%	19	81	100

suggestions in regard to removing the bottlenecks in the farm equipment industry. They require to be looked into. Some suggestions ISAE have made include establishment of a National Farm Equipment Council, a National Institute for Training in Agro-Services, a National Institute for Research and Development of Agricultural Machinery and a Farm Fuels Advisory Service.

Power-tillers

There are about 10,000 power-tillers in the country. Availability during the last 7 years is shown in **Table 5.**

This is a new technology on Indian farms. The famer is gradually accepting this source of power, but it must be admitted that the rate of acceptance is rather slow. It is expected that power-tillers will find acceptance in applications such as paddy cultivation, farming in hilly regions, orchards, vegetables and on small holdings.

Though earlier, the Ministry of Agriculture had estimated the demand by 1973-74 at 80,000 units per annum, current estimates by ISAE and the Panel on Power Tillers of the Development Council are that by 1978-79, annual demand may rise to about 20,000 units. Capacity for annual production of 40,000 units has so far been licensed (**Table 6**).

Table 6: Units licensed

Name of the unit, location and collaboration	H.P. Range 5–7 HP	8–12 HP	Total
1. Krishi Engines Ltd., Hyderabad (AKITU), Japan	3000	–	3000
2. VST Tillers Tractors Ltd., Bangalore (MITSUBISHI), Japan	–	5000	5000
3. J. K. Satoh Agricultural Machines, Kanpur (SATOH), Japan	6000	–	6000
4. Kerala Agro-Industries Corpn. Ltd., Trivandrum (KUBOTA), Japan	–	12000	12000
5. Indequip Engg. Ltd., Ahmedabad (ISEKI), Japan	10000	–	10000
6. Maharashtra Co-op. Engg. Society Shiroli (YANMAR), Japan	–	4000	4000
Total	19000	21000	40000

Only one unit has been in production and two more units have lately commenced assembly and are likely to start regular production in near future. Indigenous content has risen from 64 per cent. to 95 per cent. Imports are mostly from Japan under the Yen Credit.

Many problems of the power-tiller industry are common to those of the tractor industry and have been covered by ISAE report on bottlenecks in the farm quipment industry and the report of the Panel on Power Tillers of the Development Council. Heavy investments have been made on production facilities. Market size being small, volume of production is low. Production, therefore, is uneconomical. Yet the industry must invest in research and development and in development of markets for popularisation of power-tillers. The industry needs lot of support and suitable incentives and is expected to rough it out for quite a few years.

Other Items

Combines: It is estimated that there are about 500 combines now in India—about 300 tractor mounted PTO operated combines, indigenously assembled plus about 200 self-propelled combines imported from countries like Germany (both West and East) and USSR. A few combines have also been imported from U.S.A., Canada, Italy and Japan. The use of combines has resulted in timely harvesting of high yielding varieties of crops, reduction in cost of harvesting and great savings through significant reduction in grain losses. Main success has been on wheat crop, though combines are now being used on paddy also. Combines can also handle crops like jowar, bajra, maize, gram, soyabeans etc. and as we gain more experience of coobines, oore crops and larger acreage will be serviced by these machines. Combines have been a great success with custom operators.

Current estimates of annual demand are about 200 self-propelled machines and an equal number of PTO operated machines. NCAER has been asked t assess the demand for combines and their impact on displacement of labour and their report is awaited.

As an alternative to combines, there is a market for reapers, binders and threshers. Though threshers are manufactured at an estimated volume of 30,000 units a year, mostly by the small-scale industry, its design does require scientific study to save excessive power losses and improve the operating efficiency. Reapers and binders require further R&D efforts.

Agricultural Discs: Bulk of the discs are used on disc harrows in sizes 22" and 24" dia. Discs in larger diameters are used on disk plows. Estimates of annual demand for discs range from about

Table 7

Name of unit	Licensed capacity (Nos.)	Production		
		1969	1970	1971
1. Agricultural Discs (I) Ltd., Bombay	1,00,000	–	32,188	71,046
2. Dates Discs (P) Ltd., New Delhi	2,00,000	12,213	N.A.	22,000
3. Gromote Tools (P) Ltd., Meerut	1,50,000	33,669	48,529	23,538
4. Murrarka Engg. Works, New Delhi	30,000	–	–	2,896
5. Watkin Mayor & Co. Jullundur City	30,000	–	–	7,000
Total	5,10,000	45,882	80,717	126,480

Table 8

Sl. No.	Name of the firm	H.P.	Sanctioned Capacity (Nos.)	Production		
				1969	1970	1971
1.	Enfield India Ltd. Madras	1.2	40,000	11,137	7,001	11,950
2.	Rallis India Ltd. New Delhi	1.7 to 3	60,000	–	–	–
3.	Veegal Engines Ltd. Calcutta	1.5 to 13.2	12,000	2,172	2,354	2,783
4.	Kirloskar Kissan Equipt. Ltd., Poona	1.7 to 3	50,000	–	–	1,738
	Total		162,000	13,309	9,355	16,471

3 lakh units now to about 8 lakh units by 1978-79. An annual production capacity, however, of nearly 12 lakh units has been created—both with the small-scale and the units registered with DGTD. Particulars on the units registered with licensed by DGTD are:

Diesel Engines: It is heartening to note that the Diesel engine market has suddenly picked up. The serious drought in several States has come to the industry's rescue. Population of Diesel engines (and pump-sets) is estimated at more than 10 lakh units and estimates of current annual demand are for over 100,000 units. It has been difficult to collect statistics on the industry as nearly 50% of the production comes from small-scale industry and a large number of small assemblers.

Electric motors: The electric motor industry continues to pass through a difficult period. As it is the industry was suffering from wide voltage fluctuations, frequent interruptions in power supply and delays in execution of rural electrification programmes. To top it all, present severe power cut in most of the States has further added to the woes of the industry. Current population of electric motors (and pump-sets) is estimated at more than 20 lakh units with an annual demand of about 2 lakh units. Here again, more than 50% of the production comes from the small-scale industry.

Power sprayers: A capacity has been created to produce about 50,000 small engines suitable for power sprayers, dusters. The details in respect of the units licensed are:

There are about 35 to 40 small-scale manufacturers, 6 to 8 medium scale and 2 to 3 large scale manufacturers engaged in manufacture of plant protection equipment. Quite a few of these units manufacture assemble power sprayers. Current annual demand is estimated at about 20,000 units.

Summing up, the farm equipment industry is one of the growth potential and vital industries. It can make significant contribution to stepping up of agricultural production. Employment potential of the industry is also quite high. It is estimated that the industry at present employs over 2 lakh persons and the direct employment potential will rise to over 7 lakh persons by 1978-79. An annual investment of about Rs. 600 crores is being will soon be made in a few farm equipment inputs alone (**Table 9**).

The figures in **Table 9** exclude investments in the processing industry and on soil conservation, irrigation and rural elctrification projects. These figures underline the vital national importance of the industry. We have no alternative to farm mechanization which will mean improved productivity, reduced costs of operation and better farmer's health with less drudgery and higher standard of living through better income.

(This paper was extracted from "the Indian Express" dated 17-1-73.)

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Table 9: Estimates of current annual investment in some farm equipment in-puts.

Sl. No.	Item	Annual requirement (Qty.)	Unit cost Rs.	Estimated annual requirement (Rs. crores)
1.	Wheel tractors	40,000	40,000	160
2.	Crawler tractors	1,500	200,000	30
3.	Power-tillers	10,000	12,000	12
4.	Engines (and pumpsets)	100,000	3,000	30
5.	Ele. pumpsets	200,000	2,000	40
6.	Plant Prot. Eqpt.	–	–	6
7.	Power-Threshers	50,000	2,000	10
8.	Combines	200	200,000	4
9.	Water-well drills	100	600,000	6
10.	Replacement parts	–	–	15
11.	Bullock-carts (Pneumatic tyred)	250,000	1,000	25
12.	Improved bullock-drawn implements	–	–	20
13.	Fuels Lubricants for farm prime-movers	2 m. tonnes		242
		Total		600

News from Co-Operating Editors

Trend and Prospects on the Design and Manufacture of Agricultural Machinery and Equipment for Rice Production in Developing Countries of Asia and the Far East Region

By R.P.Venturina (Philippines)

A comprehensive conference report on the Expert Group Meeting on the Design and Manufacture of Wetland (Rice) Mechanization, Harvesting and Threshing Machinery in Developing Countries of Asia and the Far East Region held at the International Rice Research Institute, Los Banos, Laguna on March 12-17, 1973

Introduction

An expert group meeting was held at the International Rice Research Institute (IRRI), Los Banos, Laguna which was jointly sponsored by the Institute and the United Nations Industrial Development Organization (UNIDO). In attendance were 45 experts from 15 Asian countries, 4 other countries and 4 international organizations (IRRI, UNIDO, FAO and ECAFE). In addition, 18 invitees from several agencies of the Philippine government and from the business sector were also present.

The organization of the expert group meeting was brought about by the recognition of major problems in the development and local manufacture of suitable machinery for rice cultivation. Particularly evident among Asian countries and the Far East Region are the lack of accepted mechanized practices and proven product specifications and product lines and the paucity of technical service, facilities for the collection and dissemination of useful information to the farm machinery and equipment manufacturers. The UNIDO felt that integrated efforts should be made by all those concerned to assist in the development and local manufacture of suitable machinery and equipment for rice mechanization. These objectives can be realized only if research, development and testing institutions, agricultural engineering professional societies, local enterprises and manufacturers in the industrialized countries, integrate their efforts in close cooperation with each other towards the development and local manufacture of suitable machinery and equipment.

During the group meeting, the experts extensively discussed the following:

1. Trends of wetland rice mechanization and harvesting and threshing machinery in the developing countries of Asia and the Far East Region.
2. Research, design, development and adaptation of agricultural machinery including marketing research, marketing and

other supporting facilities.

3. Transfer of technology and manufacturing techniques; and
4. Institutional arrangement and development of regional cooperation.

In addition, the group studied the different agricultural machinery and equipment developed and designed at the Agricultural Engineering Department of IRRI. The machinery and equipment were demonstrated before the experts. Ways of a more widespread manufacturing and utilization of selected equipment were examined by the group.

Also, participants in the meeting were brought to a number of local manufacturers of jeepney bodies and agricultural machinery in the Greater Manila area. During these visits, the group studied and discussed the manufacturing technology applied.

Trends of Agricultural Mechanization and Manufacturing in Developing Countries of Asia and the Far East Region

As background papers in the extensive discussion of this subject, reports of fact-finding missions and studies conducted and sponsored by three international organizations, namely: UNIDO, ECAFE, and FAO were presented to the group.

The UNIDO report was presented by two experts from the organization, Mr. G. Pellizzi and Mr. Turini and the report concernes the results of a fact-finding mission, sent by UNIDO to nine selected countries of Asia and the Far East (Burma, India, Indonesia, Iran, Korea, Nepal, Pakistan, Philippines, and Thailand). The mission examined the present situation and the development of agricultural mechanization and the manufacturing of agricultural machinery in the selected countries considering the present socio-economic and agricultural conditions. The report was a comprehensive treatise on the status of agricultural mechanization activities in the countries. The paper included the status of agricultural machinery and implement manufacture and their allied services, such as design, adaptation, testing, repair and maintenance with specific reference to rice mechanization; the nature of specific problems of their development and use and development of storage and transport equipment for use in agriculture. The report also identified selected local manufacturers in each country who may be interested in product diversification and expansion of their manufacturing facilities.

Mr. V.M. Subramanian, an expert from ECAFE presented the paper on the rice mechanization and machinery manufacture in the ECAFE countries. The report deals with the result of a fact-finding team which was sent to twelve countries in the region including Japan. The developing countries visited by the team were: the Republic of Korea, Philippines, Indonesia, Singapore, Malaysia, Sri Lanka (Ceylon), Thailand, Iran, Pakistan, India and Nepal.

It was emphasized in the ECAFE report that agricultural machinery manufacturing industry covers a wide spectrum from small scale workshops to multi-national corporation and deals with a large variety of products from hand tools to large mechanically powered agricultural tractors and machines. It was also pointed out that the problems of the industry and the policies needed for its development in the countries of the region are varied in nature and magnitude such that planning and adoption of policies are required at the national and regional levels, including financing, investment promotion and expert on the one hand, and institutional services in the fields of research and development, training and management on the other hand, with special reference to the transfer of appropriate technology. The report concluded that lack of funds and technical personnel, the absence of precision in the definition of problems and the lack of coordination in the exchange of information are some of the major reasons why there seemed to be lack of progress towards the development of the agricultural machinery industry and the development of farm mechanization.

Mr. Van Gilst, an agricultural engineer from FAO presented a background paper on the role of mechanization in agriculture. The paper which was prepared by the Agricultural Engineering Service of the FAO Agricultural Services Division discussed in general terms the requirements of farm mechanization and shifting to a more intensive type of agriculture. In defining what form of mechanization should take now and in the future in any given country, the paper stressed, factors influencing mechanization such as rainfall, soil, farm sizes, cropping patterns, etc. should be examined to the degree appropriate to each problem related to mechanization, including social implication. The paper presented the future development of agricultural mechanization in developing countries and the FAO strategies in this sector. Mr. Van Gilst pointed out that with regard to mechanization, it is FAO's policy to establish closer contact between institutions in developing and developed countries aiming at finding economic and socially acceptable solutions to common problems.

During the discussion that followed after the presentation of background papers the group of experts reached the consensus that to supply sufficient and high quality food to rapidly growing population of the region, there is an urgent need for increased

The expert group meeting held at IRRI

wetland rice production. To achieve this, a shifting of the prevailing types of agriculture to more intensive farming systems is necessary. Such systemes include the use of new varieties, a higher level of management and a higher power input. Although it is estimated that the total labor force in the paddy areas will not substantially decrease in the next two decades, such a higher power input can only be achieved by the development of the mechanization through the improvement of animal drawn implements and the gradual introduction of mechanical power operated equipment. There was an agreement that the role of such mechanization applied in the Region should be aimed at an increase of the overall level of employment by covering seasonal labor peaks, increasing soil productivity by timeliness and quality of the cultural practices improvemet as well as reducing losses and cost of paddy production.

As the farming and socio-economic conditions show wide variations among within countries, the experts recommended that for each country and district specific mechanization policies be defined considering the following:

(a) Contribution to the level and quality of food production;
(b) Investment and crediting policies involved;
(c) Cost/benefit ratio for the individual farmers;
(d) Impact on the level and quality of employment on the farm, as well as in the manufacturing distribution and other levels of industry;
(e) Creation and extension of employment in the manufacturing and other related sectors and other benefits of introduction of industrial technology in the rural areas; and
(f) Purchasing power of farmers and an analysis of the price structure of the country.

From the available information presented, it was evident to the group that substantial increase of available power per hectare will be indispensable to obtain a more intensive agriculture. To indicate: An increase of the present amount of power per hectare of cultivated land available (0.2 HP/ha.) up to a minimum of 0.5 HP/ha. in the next decade seems desirable. It means, for the 60 million hectares of paddy land of the 9 countries visited by the UNIDO team, the necessity of an additional minimum power of 18-20 million HP of motorized equipment has to be added.

It was emphasized during the discussions that the size, the type of tractors and other agricultural equipment characteristics depend on the selected profitable farming systems and local economical conditions. Selection of size and type depend on the goal of maximum reduction of production costs of paddy and with reference to the average purchasing capacity of the farmers.

The experts agree that because of the small average size of the paddy farms in most of the countries in Asia and the Far East Region and after unfavorable conditions for large scale mechanization there is a need to develop and to manufacture low-cost, durable and simple to manufacture, to use and to maintain farm machinery and equipment. In view of this, it was urged by the group that intergrated efforts should be made by all those concerned to assist developing countries in the development, design and local manufacture of suitable machinery and equipment for agricultural mechanization.

The group of experts predicted that there shall be an increasing demand for agricultural machinery and equipment. To meet this increasing demand, it was strongly recommended that regional coordinated policies and goals for manufacturing of agricultural machinery should be developed in each county. Such policies, it was pointed out, should be defined in close cooperation between research, design and testing institutes, farm planning and financing institutions, dealers and manufacturers with the assistance and cooperation of local and international organizations.

It was noted by the group that the present facilities of existing small to medium size manufacturing plants use intermediate manufacturing technologies and that these plants can provide the small farmers with the farm tools animal or power equipment required for intensive wetlant agriculture. Development of these plants is, therefore, important and dissemination of information on promising types of tools and simple low-powered multipurpose equipment should be given closer attention by research institutions.

In planning for the development of local manufacturing industries, the experts suggested that the following be taken into account:

(a) At present the potential capacity of various enterprises is not used to its full extent and on the average, does not exceed 50% of production capacity;

(b) The application of production engineering and product planning and principles and techniques need to be strengthened;

(c) More attention should be given to training and extension of adequate use, maintenance and repair of agricultural machinery and equipment;

(d) There is a great need to standardize machine parts and type. Production targets should be based on economies of scale and that specialization and coordination in manufacturing should be encouraged.

To achieve developmental goals in the area of agricultural machinery and equipment, manufacturing, the experts urged that the national government in the respective countries promote agricultural mechanization by giving support in the establishment of pilot plants, promotion of training and extension facilities both on the manufacturing and the farm level and by enlarging the credit and other facilities for these purposes.

Research, Design, Development and Adaptation of Agricultural Machinery

Five documents were presented concerning general and particular problems, the development of an appropriate mechanization technology, the national policies for research and development, the manufacturing potential in the less developed countries and the problems of marketing of locally manufactured farm equipment.

The background paper for this topical group discussion was provided by Dr. B. W. Giles, a UNIDO expert in Agricultural Engineering. In his paper, Dr. Giles discussed the intimate relationship of manufacturing with that of design, development, adaptation and testing. These are classified by Dr. Giles as "input services" in contrast to sales, parts supply, repair services and demonstration, which are termed "output services". According to the author, Asia has uniqeueness, such as multiple cropping, that make input services in the region necessary. This region cannot rely solely on using or simply copying imports. Dr. Giles mentioned the success of a project in India in the design, development and manufacture of a grain drill adapted to the special agronomic and physical conditions of the country wherein over 12 percent increase in wheat yields was attained.

Dr. Giles concluded that many of the machine design and development problems of the nations within Asia and the Far East region required the application of identical principles such that there is a great need for the establishment of a regional design and development centers. The author added that because of the great potentials of multiple cropping among centers, regional or otherwise, design and development should not be restricted to one crop activities.

Another paper on the subject was presented by Dr. Amir U. Khan, agricultural engineer at IRRI. The paper dissected the efforts of nearly 25 years to mechanize tropical agriculture and concluded that these efforts have not made meaningful impact on the majority of the farmers with small holdings in Asia. Among others, Dr.Khan emphasized that:

(a) Widespread mechanization of agriculture will be possible only through a concurrent growth of the farm equipment manufacturing industry in the region;

(b) The requirements of the farmers with small holdings and the small fabricators of agricultural machines must be the important criteria in selecting mechanization strategy for the countries of the region;

(c) Indigenous manufacture of simple, low-powered equipment offers the best possible approach for the mechanization of tropical agriculture because such strategy will not create too many adverse social and economic imbalances; and

(d) To accelerate the development of appropriate technologies, capabilities of the farm equipment industry in the private sector must be developed through a more direct support and intervention from the public sector in the region.

Joint Commissioner D. N. Kherdekar of the Ministry of Agriculture of India presented his paper on national policies for research, development and adaptation regarding agricultural machinery. The paper discussed

The Jeepney in the Philippines

mainly the institutional arrangements in India regarding research, developmental, adaptation and testing of agricultural machinery. In his paper, Mr. Kherdekar emphasized that it is necessary to coordinate the research and developmental activities of various sector institutions, departments, universities and private centers. This coordination has to be done at the national level in order to avoid duplication of work and to obtain the results as soon as possible.

Mr. Fred E. Nichols, IRRI Associate Evaluation Engineer presented his paper on manufacturing potential in the developing countries. The author mentioned the projected annual requirements for eleven (11) countries of Asia in 1975 for four (4) key equipment as gathered from two sources as follows:

Four wheel riding tractors	120,000
Power tillers	81,800
Small engines	941,000
Power-operated threshers	117,500

Mr. Nichols indicated that with appropriate design and production technology, this need may be met through local production. The author cited the experience of Thai Heng Long Ltd. in Thailand which produces 1,000 gasoline engines (10-30 HP) per month using mostly locally fabricated equipment and the jeepney industry in the Philippines which has successfully fulfilled a primary need through local production.

Mr. Edilberto A. Uichanco, an agricutural engineer and Vice President, Marketing Division of the G.A. Machineries Inc. of the Philippines read his paper on marketing of locally manufactured equipment in a developing country. In his paper, the author discussed the basic functions of marketing and the pitfalls of new product introduction and development. Product innovation is the key to successful marketing. It is, however, wrought with problems and the risk of failure can be great. The author presented the major reasons for new product failures which are as follows:

(1) Inadequate market analysis;
(2) Product defects were not caught in the performance or market test;
(3) Higher cost than anticipated;
(4) Poor timing;
(5) Insufficient marketing effort;
(6) Inadequate sales force or lack of its support because of existing products in its selling package; and
(7) Weakness in distribution or not having the product where and when the product was created.

During the discussions of the group on this theme, it became evident that various developing countries have many research studies and development activities for rice mechanization, machinery and even in the same country different institutes may be duplicating the same work. The meeting recognizes the need for better coordination of these activities and that it is suitable to establish a committee to help rationalize the designs and types of agricultural machinery most suitable for the region considering social, farming and economic conditions. This committee would coordinate results of functional and economic feasibility study, prototype testing, improvement and production and avoid duplication. The committee has to operate in coordination with IRRI so as to study the suitability of manufacturing of IRRI prototypes in all the developing countries from the point of view of manufacturing capability, availability of raw materials, etc.

The experts recognize that rice mechanization machinery constitutes a wide spectrum of product ranges from hand tools to power machinery and various production technology. The production consists in small, medium and large scale sector. There is a need to assist small and medium scale manufacturers in design and development activities and small and medium scale factories have to be encouraged and be considered in national policies because of their labor-intensive and their versatility in production lines.

The group discussed the need for rationalization and standardization of products from the import as well as from the local manufacturers points of view to be put in the research and development activities. Policies, the experts pointed out, should include establishment of national repair and maintenance program, central workshop and spare parts inventory control.

As far as marketing problems are concerned. the group emphasized the need for conducting consumer or market surveys first before launching the production of a new product line. The new product should have exclusivity to make up for initial losses. It is also extremely important that the operators and purchasers are trained properly in handling and in the maintenance of the machine produced.

Insofar as UNIDO assistance in this area is concerned, the group of experts recommend that:

(1) UNIDO promote an integrated activity in the developing countries either through reinforcement of existing facilities, and the organization should place emphasis on making aware the inter-relationship between design, manufacture and consumer requirements;

(2) UNIDO initiate a program to assist the governments of developing countries in the selection of right type of mechanization machinery to acertain the level and degree to suit local conditions and needs by providing experts and data on the machinery already designed and developed by some countries.

Degree of rice mechanization and selection of type of machinery would depend upon the following factors:

(a) Manpower availability and labor rates;
(b) Land physical characteristics, availability and conditions;
(c) Political and economic conditions of the country; and
(d) Availability of skilled manpower.

In this context, the group recommends that UNIDO place emphasis on making aware the inter-relationship between design, manufacture and consumer utility.

(3) The UN organization promote the establishment of a committee to help rationalize the designs and types of agricultural machinery most suitable for the region considering social, farming and economic conditions. This committee would coordinate results of functional and economic feasibility studies, prototype testing, improvement and production and avoid duplication.

(4) UNIDO, at a national level, promote technical consultation meetings between industry and design and development instituions and assist in the formulation of practical industry-oriented development work program, and that.

(5) UNIDO, assist developing countries in the establishment of national repair and maintenance and after-sales services program.

Manufacturing Techniques; Problems and Technology Transfer

Under this area five papers were presented before the experts concerning the following topics: capital versus labor intensive manufacturing strategies; techniques of sub-contracting institutional credits; promotion; and techniques and problems of agricultural machinery manufacturing in different companies.

The papers under this topic were presented by Dr. Bart Duff; Economist in the Agricultural Engineering Department of IRRI; Engr. Ceferino L. Follosco, Vice President for Manufacturing of Ford Philippines; Mr. Benjamin Catane, Head of Small Business Loans Dept., FNCB Finance, Inc. (Philippines); Mr. V. R. Reddy, Managing Director, Krishi Engines Ltd., (India); and Mr. T.N. Jinasena, Managing Director, Jinasena Ltd., Engineers (Sri Lanka).

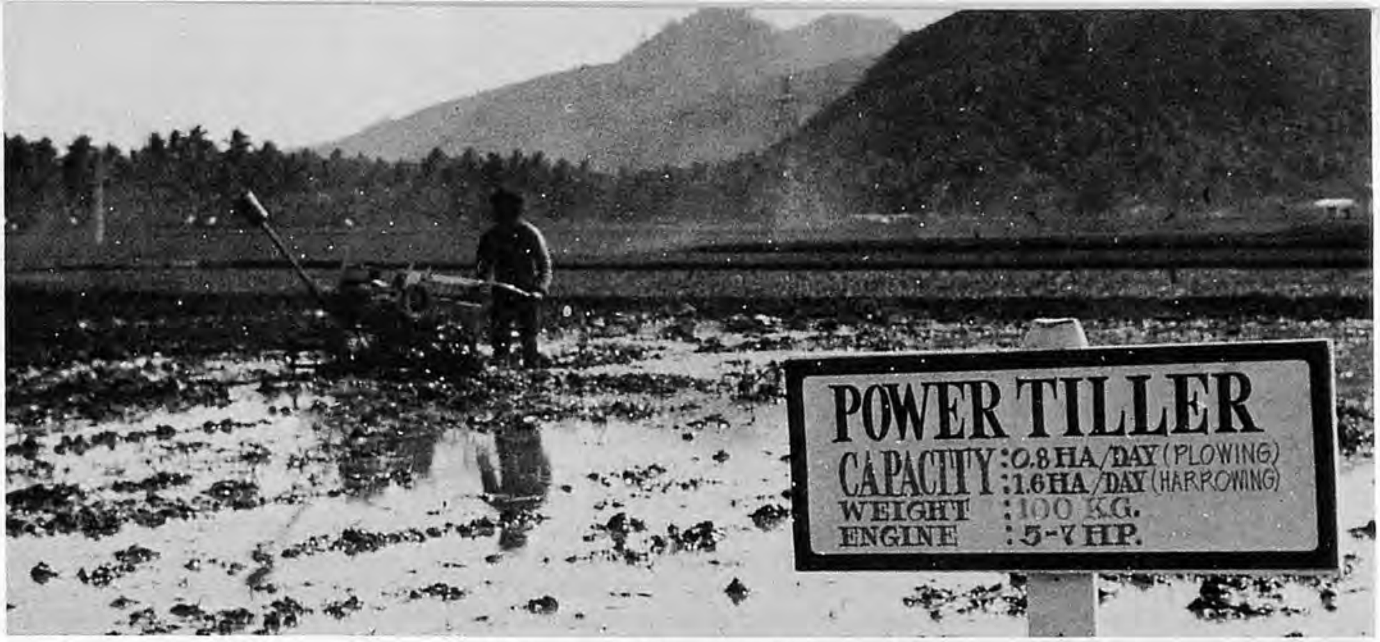
Dr. Duff discussed the need for studying carefully the strategies that should be followed in the development of manufacturing industries. He stressed that selection of strategies shall depend on capital available, labour, expertise and volume of business.

Mr. Follosco presented the merits of subcontracting to accelerate the development of manufacturing industries. He pointed out that in a developing economy which generally lacks adequate resources and expertise, subcontracting is the fastest method of promoting the manufacture of agricultural implements and machinery. Mr. Follosco enumerated the advantages of subcontracting as follows:

(1) It greatly reduces the investment in manufacturing facilities normally required in a fully integrated manufacturing operation;

(2) It enables plants which are under-utilized to be fully utilized. Surveys conducted in some developing countries indicate that even on an 8-hour shift, many manufacturing concerns do not operate at full capacity;

(3) The seasonality of market demand generally common for agricultural implements and machinery require a flexible manufacturing operation. Subcontracting provides the most e-



Power tiller (engine : 5~7 HP, weight : 100 kg)

conomical solution to such a problem;

(4) While not generally true at the start, costs are lower due to the achievement of economies of scale, specialization and lower labor and overhead costs.

The author warned that the biggest setback encountered in subcontracting are poor quality and failure to meet delivery schedules. This tends to be a disincentive for horizontal integration or subcontracting and therefore leads manufacturers to vertically integrated manufacturing operations, as what exists presently in agricultural machinery manufacturing in many developing countries.

Mr. Catane discussed extensively one of the major problems of promoting and developing industrial activities—the lack of credit facilities. Mr. Catane noted that institutional financing encompasses the greatest range of borrowing variations that business firms utilize. In developing countries, the most common institutional sources of financing are: state development banks, private development banks, commercial banks, state banks, commercial finance companies, pension and welfare funds, investment banks, rural banks, cooperative societies or banks, and special small industries fund.

The author pointed out that financing of small industries, even medium-sized enterprises, is always a risky undertaking, and lending institutions (except special small industry funds) have reasons to be reluctant to finance this size of enterprises. Mr. Catane summarized the biggest "bottlenecks" in lending to the small firm follows:

(1) **Low equity base.** Many entrepreneurs start their business with very small, if any, equity and expect lenders to provide the balance of the capital needed to operate the business;

(2) **Quality and depth of management.** The management of a small firm is concentrated in one individual or family, who in many cases does not possess management depth.

(3) **Inadequate financial records.** Small firms in many cases, do not keep adequate financial records on which the lending institution is able to assess its historical performance, particularly in the company's earning record. In case of start-up operations, the small entrepreneur is not able to present sufficient information on company's plans and strategies, forecasts, and financial projections.

(4) **Vulnerability to even the slightest economic dislocation.** Because of its size, the small firm is very sensitive to even temporary economic reversals. For instance, increase in raw material costs, or a minor drop in sales volume for some reason, or a delay in collection, or slow-down in production, can greatly affect its cash generating ability and eventually its debt repayment ability

(5) **Return to the lender not commesurate.** The "yield" of the loan to the lender is often not commensurate to the risk and time and expenses involved in giving a loan to a small firm.

Mr. Catane emphasized, however, that the above problems and difficulties in lending to a small firm should not in any way preclude assistance to small industries. He added that governments should actively "persuade" financial institutions, including commercial banks to allocate a percentage of their loan portfolio for lending to small, but viable enterprises.

Mr. Reddy presented his paper concerning the problems and promotion of manufacture of agricultural implements and machinery in India. The author mentioned that the objective of mechanization is to increase productivity. Specifically in India the objective is to increase the productivity per unit of water available for agriculture, as this is perhaps the most scarce resource. An important secondary objective is to increase production per unit of land. These objectives are quite different from the objective of some other countries where the need is to increase the productivity of man. The author traced the development of agricultural mechanization in India. Mr. Reddy concluded that while there is no doubt that the future of agricultural machinery and improved implements industry is very bright in India, certain important decisions and steps have to be taken both by the industry and government to accelerate the tempo of mechanization. One important factor to consider is the need to take a second look at the designs of the machinery introduced from other countries to suit the conditions that are prevailing in India. Also, in view of the land ceiling that is being legislated in the country, there is an urgent need for developing a low horsepower (12-14 HP) tractor for the dry land areas and a simple inexpensive power tillers (5-7 HP) for rice culture.

In his paper presented to the group of experts, Mr. Jinasena emphasized that the need for each developing country to foster its indigenous industries to provide its requirements of agricultural implements and machinery has been clearly established. The author added that the developing countries do not possess the necessary background of technical expertise to copy directly the technological methods and manufacturing processess of the Western countries such that the immediate need is to develop an intermediate technology which is not too large a step away from the current level of expertise, but which will enable the production of simple, well-made and useful agricultural implements and powered machinery.

Based on these documents and on the discussions during the meeting, the following conclusions and recommendations were made:

(1) Regarding the choice of manufacturing techniques, the consensus of opinion was that it should be carefully done by taking into consideration the capital available, labour expertise, the volume of manufacture and other factors.

(2) Sub-contracting is a very useful technique in increasing manufacturing capacity as it offers the advantages of specialization and less cost. It also offers a dispersal of wealth to narrow the gap between the rich and the poor. However, the quality of product and time of delivery have to be ensured by the sub-contractors. It needs to be introduced quickly in this area if necessary with the assistance of local trade association.

(3) Sub-contracting needs good quality control, proper orgainzation, standardization, engineering expertise and other infrastructure which should be created by the technical sources and small scale industries organizations in the Asian countries.

(4) Institutional finance needs to be made available to the entrepreneurs for the establishment of factories and workshops for manufacture of agricultural machinery and implements. The establishments of special facilities and protections have also to be recommended.

Special quota for foreign exchange may be alloted to agricultural machinery manufacturers in case they have to import capital goods or raw materials.

(5) It was recommended that the governments in South East Asian countries should give special concessions for the introduction of newly designed machines, and should simplify the licensing procedures for industries.

(6) Careful market survey should preceed actual selection and implementation of any manufacturing project. Encouragement should be given for inventing new ideas and in the introduction of new innovation.

(7) In South East Asian countries, intermediate technology may be applied wherever possible specially in developing countries. This is necessary because special and sophisticated types of tools are required for applying mass manufacturing techniques adopted in the industrially developed countries.

(8) It was proposed that IRRI may undertake designing of diesel power tiller preferably with sitting arrangements and a 5 to 18 HP four-wheel tractor.

(9) Broad specialization of products on selective basis has to be undertaken on international basis cooperating both in production and sales.

(10) Engineering courses with strong practical bias should be promoted to train engineers in the developing countries.

(11) The difficulties were pointed out by the manufacturers regarding transition period between simple to complex. It was considered a very critical stage particularly for small firms. This being a management problem, it was suggested that manufacturers should take this with advisory councils of research stations to solve this problem.

Institutional Arrangement and Development of Regional Cooperation

The group of experts also discussed extensively institutional arrangements and ways of promoting regional cooperation for the development of the industries relating to agricultural machinery manufacture. The experts noticed with great interest the concept of the establishment of a regional Agricultural Machinery Institute for Asia and the preparatory activities carried out by UNIDO, ECAFE and IRRI.

From the presented information and discussions of the experts it was strongly recognized by the Group that there is a need for coordinated activities at the regional level with a view to support and not to duplicate the national activities and to promote international cooperation in the Region.

The group fully supports the establishment of this Institute as a most adequate instrument for conducting activities and to maximize utilization of existing facilities and resources and recommends strongly to the international organizations concerned as well as to the national governments concerned to take all future steps to the proper implementation of this proposal as soon as possible taking into account the available funds and by application of a pragmatic approach on this matter.

The experts estimate it as highly desirable that a formulation committee should be set up to prepare the terms of reference, the work programmed and other institutional matters of the Institute. It recommends also that both the public as well as the private sector of the agricultural machinery industry be represented in that committee.

The experts recognized the contribution of UNIDO and other international organizations in contributing to the development of agricultural machinery industry at national and regional levels and the limitation of finance at the disposal of United Nations including UNIDO. However, the experts recommend that technical personnel of the developing countries should assist the Governments concerned to include programs in agricultural machinery for United Nations and UNIDO assistance in cooperation with allied international organizations. The group also recommends that UNIDO together with ECAFE and IRRI assist the Governments of developing countries in working out programs for technical assistance. The group also commends the work undertaken by IRRI in development of manufacturing prototypes of agricultural machinery and implements for rice mechanization and identifies this activity worthy of promotion for manufacture in other developing countries of Asia and the Far East. In this connection, the experts recommend that UNIDO initiate an integrated activity for promotion of manufacture through provisions of IRRI prototypes, providing fellowships and assistance in manufacture at local industry level through appropriate UNIDO financial resources.

The experts noted that information dissemination among developing countries should be enhanced and recommended that UNIDO explore the possibilities of assisting commercial publications through private publishers and sales channels. It was realized by the experts that there is a need for dissemination of information on a wider basis not only among the Government officials but also among the manufacturers, distributors and end-users of agricultural machines. Serious consideration must be given to have periodic publications to be circulated in the Region both through the existing commercial publication channels as well as through international organizations which would periodically give reports and news on all kinds of developments that are taking place in the Region. Also market surveys, if any conducted, and imports from developed countries may be included in this publication.

Conclusion

The expert group meeting was successfully concluded with the identification of problems and solutions in the development of agricultural machinery manufacture in Asia and the Far East region. What remains to be done is for the developing countries to pursue vigorously updated programs considering the recommendations and suggestions of the experts. Representatives from developing economies recognize the contributions of UNIDO, ECAFE and other organizations including the assistance of advanced countries in the rapid development of agricultural machinery and equipment manufacture in their respective areas. It is hoped that with this recognition, these organizations and advanced countries will always extend a helping hand for the development of agricultural machinery and equipment manufacturing industry in the region. ■ ■

News from Co-Operating Editors

Other News from the Philippines

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Filipino Agricultural Engineers Elect Officers

The Philippine Society of Agricultural Engineers during its business meeting held recently elected new sets of officers for the 1973 term.

Elected president was Engr. Rogelio C. Lazaro, Chief of the Agricultural Development Office of the Upper Pampanga River Project in Cabanatuan City, Nueva Ecija. Mr. Lazaro obtained the highest rating in the first Board Examinations for Professional Agricultural Engineers in the Philippines. A Master of Engineering degree holder from the Asian Institute of Technology in Bangkok, Mr. Lazaro is a Fellow of the Economic Development Institute of the International Bank for Reconstruction and Development (IBRD).

Other officers elected were Mr. Heculiano A. Sabas, Vice-President and the following as Directors: Mr. Rodolfo G. Domingo; Teofilo Ferraris; Guillermo P. Santos; Edwin Karganilla; and Benito C. Gonzales. After the elections, the new set of officers appointed Mr. Faustino G. Cueto as Executive Secretary; Miss Teresita C. Castaneda-Treasurer and Miss Judy Maramba-Assistant Secretary/Treasurer.

IRRI Hosts Expert Group Meeting

The International Rice Research Institute at Los Banos, Laguna hosted recently the expert group meeting on the design and manufacture of wetland (rice) mechanization, harvesting and threshing machinery in developing countries of Asia and the Far East Region. The meeting which was held on March 12-17, 1973 was co-sponsored by the United Nations Industrial Development Organization (UNIDO).

The meeting was attended by 45 agricultural machinery experts from 15 Asian countries, 4 other countries and 4 international organizations (IRRI, UNIDO, FAO and ECAFE). In addition, 18 invitees from several agencies of the Philippine government and from the business sector were also present. The Asian and other countries represented in the meeting include: Australia, Bangladesh, India, Indonesia, Iran, Italy, Japan, Khmer Republic, Korea, Laos, Nepal, Netherlands, Pakistan, Philippines, Singapore, Sri Lanka, Thailand, USA and Vietnam.

During the group meeting, the experts extensively discussed the following:

1. Trends of wetland rice mechanization and harvesting and threshing machinery in the developing countries of Asia and the Far East Region;
2. Research, design, development and adaptation of agricultural machinery;
3. Marketing research, marketing and other supporting facilities;
4. Transfer of technology and manufacturing techniques; and
5. Institutional arrangement and development of regional cooperation.

A more detailed report on this important meeting is included elsewhere in this issue of the Journal.

Agricultural Engineers Hold Technical Meeting

An annual technical meeting was held recently by the Philippine Society of Agricultural Engineers at the Social Hall of the Agricultural Credit Administration and conference hall of the Liberty Flour Mills Inc. During the two-day meeting, Dr. Joseph Madamba, Director-General of the Philippine Council for Agricultural Research and Mr. Teofilo Azada, Administrator of the Agricultural Credit Administration were invited as guest speakers.

The technical papers presented by the members of the Society include the following:

1. A Program for Farm Mechanization in the Philippines (Dr. Reynaldo Lantin, Assistant Professor, U.P. College of Agriculture)
2. A Development Strategy for the Grain Industry in the Philippines (Dr. Dante B. de Padua, Chairman, Agricultural Engineering Department UPCA)
3. Agricultural Engineering Research: A Vital Component Research of the Philippine Council for Agricultural Research (PCAR) (Prof. Andres P. Aglibut, Director, PCAR)
4. Rice Drier Development at the International Rice Research Institute (IRRI) (Mr. Antero S. Manalo, Assistant Design Engineer & Mr. Jose R. Arboleda, Research Assistant, IRRI)
5. Development and Operation of the Seed Processing Plant of the Maligaya Rice Research and Training Center (MRRTC) (Mr. Rodolfo Domingo, Assistant Chief, Agricultural Engineer, MRRTC, Bureau of Plant Industry)
6. Design, Development and Operation of a Centralized Curing Barn for the Virginia Tobacco Industry in the Philippines (Mr. S.C. Andales, Assistant Professor U.P. College of Agriculture)
7. Compact Farming (Mr. Herculiano A. Sabas, Chief Engineer, Agricultural Credit Administration)
8. Power Tiller and Tractor Developments at IRRI (Mr. Jose S. Policarpo, Assistant Design Engineer IRRI)
9. A Climatological Handbook for Philippine Agriculture (Mr. Mario G. Gulinao, Araneta University Foundation)
10. Role of Agricultural Engineers in Accellerating Community Development (Mr. Fabian Abella, Department of Local Government and Community Development)
11. The Shallow Well Pump Irrigation System (Mr. Teofilo Mendoza, National Irrigation Administration)
12. Development of Communal Irrigation Systems in the Philippines (Dr. Petronio S. Ongkingco, Assistant Professor U.P. College of Agriculture)
13. Determination of Effective Rainfall, Farm Waste, Water Use Efficiency and Total Water Use (Mr. Sebastian Julian, National Irrigation Administration)
14. Rainfall Frequency, Duration and Intensity for Use in Local Drainage Systems Designs (Mr. P.V. Tabanao, U.P. College of Agriculture)
15. Appraisal Study of a Farm Machinery Testing Project (Mrs. Lorna P. Domingo, U.P. College of Agriculture)

Just after the technical meeting, the new registered professional agricultural engineers were inducted by Mr. Luis Fran, Chairman of the Board of Examiners for Agricultural Engineers. Also, certificates of Recognition by the Board of Examiners were awarded by Mr. Fran to Director Felix Maramba Sr., Mr. Julian Bulanadi and Mr. Guillermo P. Santos for their outstanding achievements in the field of agricultural engineering.

PSAE Revives Publication of Agricultural Engineering Journal

The Philippine Society of Agricultural Engineers during a meeting of the Board of Directors recently revived the publication of the Philippine Agricultural Engineering Journal. The publication of the quarterly was temporarily stopped in 1968 due to lack of funds.

The Board of Directors of PSAE appointed the following as members of the Committee on Publications: Director Felix D. Maramba Sr., Chairman; Dr. B. de Padua, Member and Mr. Faustino G. Cueto, Member while the following were selected contributing editors: Dr. Reynaldo M. Lantin (Power and Machinery); Mr. Teofilo M. Mendoza (Soil and Water); Dr. Manuel Vergel, Jr. (Structure and Environment); Mr. S.C. Andales (Processing); Prof.Crispin R. Las Marias (Research and Education); Mr. Ricardo P. Venturina (New Products); Mr. Herculiano A. Sabas (Industrial Department); and Mr. Faustino G. Cueto (News). ■ ■

News from Co-Operating Editors

The Present Status of Agricultural Mechanization in Bhutan

Shri M. B. Gurung
Exparticipant O. T. C. A. Japan
(R. A. R. S. Lutifu Bhutan)

The present status on Agricultural mechanization in Bhutan is in still infant stage. However the Government is trying to promote the Agricultural equipments in different vicinity.

In order to get the sufficient yield from every unit of land, we need more manual power, anyway our country like Bhutan, there are multiway to get the labour force in cheaper rates.

The rapid development in Agriculture can be attained through the improved handy machines, chemical fertilizers and improved seeds so on.

Drawback in Agriculture Mechanization in Bhutan.

1. Fuel cost is very high.
2. Spare parts are not available proper time.
3. Lack of general education of farmers.
4. As there is no any secondary ocupation of the farmers after completely mechanized.
5. Lack of trained mechanic.
6. Lack of servicing centre to each vicinity.
7. The cost of machine is very high.
8. The field efficiency of machine is not sufficient due to small land holding.

According to the topography of Bhutan we can assure that the rapid development in Agriculture can be extended through the simple bullocks drawn implements in such type of small terraced lands.

First of all, we have to modify the simple implements, according to the soil gravity in the different regions of Bhutan.

At present we are importing only iron plough from India and other materials (wooden) are available in our own country.

Generally, our farmers are in habit of using wooden local ploughs which they prepare within a short period with less labour, but these are not durable like improved bullocks drawn M. B. ploughs. Since last year we are usining those improved simple bullocks drewn implements which are quite durable in comparison with the local made ploughs. So we hope that the simple bullocks drawn implements are quite applicable in the terraced hilly region of this locality.

At present the Goverment has imported few numbers of powertillers from India to use in agriculture field in Bhutan.

Particulars of Machine

Name of machine: Krishi Power-tiller (Indian made).
P.S.: 5.5
Engine: Diesel oil (water cooled) horizontal type.
Location: New farm at Simtokha, Thimphu Bhutan.
Date: 15. 11. 72.

In course of time Bhutan will be self sufficient in rice without bringing any additional land under rice cultivation. We have confidence that farm machinaries will play a very vital role to change our traditional rice cultivation system and will sustain not only the farmers income level but also of the national economy as well.

■ ■

Data Obtained from Utilization of the Said Machine

Name of machine.	% of moisture in siol	Speed & gear	Previous crops in the field	Next crops	Depth of ploughing	Acre/ Time
Krishi Power-tiller Max. output 5.5P.S.	Moderate	III Gear	Paddy	Wheat	10-15cm	½ Ac/day
One pair of Bullock	–do–	–	–do–	–do–	15-20cm	½ Ac/day

Agricultural Development Bank of Nepal

B. K. Shrestha
Assistant Agr. Engineer,
4/141 Pulchowk, Lalitpur,
Nepal

For the development of agriculture, Agricultural Development Bank of Nepal has been helping to the majority of Nepalese farmers providing loan in simple condition to purchase the required farm inputs and agricultural machineries. Such help to the farmers is necessary to increase the creativity of Nepalese farmers to purchase farm inputs and thus improve the farming system. The following table shows the loan given by the Bank in different purposes.

Above mentioned loan has been divided into cooperations, individuals and corporate bodies as follows.

The loan granted in the fiscal year 1971-72 for Farm Machineries and Irrigation the following table shows loon distribution on different stems.

(in thousand)

Items of loan granted	Fiscal year *		
	1970/71	1972	%
1. Food grain & cash crop	49,58	1,12,36	126,6
2. Farm machinery & irrigation	62,82	60,35	−3,9
3. Farm Business	22,66	20,47	−9,6
4. Horticulture	2,33	1,75	−24,8
5. Tea garden	22,39	9,00	−59,8
6. Sales and godown construction	13,85	7,42	−46,4
7. Agri. Industries	18,47	23,29	26,0
Total	1,92,10	2,34,64	22,1

* Nepalese fiscal year lies between mid june to mid. may.

1.	Artisian well	384
2.	Tractors	2798
3.	Implements	168
4.	Power tiller	208
5.	Thresher	3
6.	Sprayer	12
7.	Purchasing Animals	427
8.	Pump-sets	1846
9.	Tube well	100
10.	Hand Tube well	12
11.	Construction of canal	75
12.	Fencing	2
		6035

(in thousand)

	Fiscal year		
	1970/71	1971/72	%
1. Cooperationes	22,49	41,17	83,1
2. Indiciduals	1,40,13	1,63,12	16,4
3. Corporate Bodies	29,48	30,35	2,9
Total	1,92,10	2,34,64	22,1

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INDEX TO ADVERTIZERS

New Books

Agricultural Meceanization in Developing Countries

Edited by
Merle L. Esmay[*]
Carl W. Hall[**]

The book has eight chapters prepared by eleven different recognized authorities in the various fields of agricultural mechanization. The authors collectively have some thirty years experience in the developing countries of the world.

Many publications present the viewpoints of economists and social scientists on agricultural mechanization as part of the total agricultural production picture; however, a reference pertaining more directly to the technology of agricultural mechanization has not previously been published. The book pertaints to agricultural mechanization and related effects. Much of the material has been tested previously in professional articles, talks, seminars and classroom discussions, and perhaps more importantly, as a part of many action programs in several countries throughout the world.

Principles of mechanization of agriculture are defined in the context of developing countries within the inter-relationships of the many segments of the society and the economy.

[*] Professor of Agricultural Engineering.Michigan State University

[**] Dean of Engineering, Washington State University

6 × 8.5 in., 221 pages, hardbound.
Published by the Shin-Norinsha Co., Ltd., 7-2 Chome, Kanda Nishikicho Chiyoda-ku, Tokyo, 101. Japan.
May be ordered from Shin-Norinsha Co., Ltd. Price is US $9.00 (Soft cover : US $5.00)

■ ■

Manual of Pestcide Application Equipment

New manual covers 30 categories of pesticide application equipment

The universal trend toward intensive agriculture has created a need for practical information about crop protection equipment. The International Plant Protection Center has just published a MANUAL OF PESTCIDE APPLICATION EQUIPMENT to help meet that need.

The new 130-page Manual covers hand operated and engine powered applicators—for dust, granule, and liquid—as well as pumps, nozzles, tanks, and other components, plus operator safety gear. Thirty different categories include products manufactured by 253 firms wordwide.

Each of the 30 product classifications lists the names of all known manufacturers of that item. A second section contains each firm's name/address and a cross reference to specific categories.

A special Feature Products Section with more than 200 photos and drawings includes an illustration and brief technical description for reperesentative units from each classification.

Manual of pesticide Application Equipment 2-2-2-2-2

The Manual was designed as a handy information tool for agriculturalists, researchers, students, and all who are concerned with crop protection. Being primarily intended for use in developing countries and for research, the publication emphasizes—but is not limited to—equipment suited to small scale land units.

The introduction and category headings are printed in English, Spanish, and French. All dimensions are given in both English and metric units. Material for the Manual was gathered and edited by A. E. Deutsch and A. P. Poole, IPPC staff members and former Peace Corps volunteers.

To minimize costs the Manual was issued as a "paperback," but with heavy duty covers and a plastic spiral binding. Individual sections are printed on different color paper for ready identification. Page size is approximately 8.5 x 11 inches (21.6 x 28 cm).

The Manual costs $4.00 US per copy surface postage paid from: Internaitonal Plant Protection Center, Oregon State University, Corvallis, OR 97331/USA.

Other publications from IPPC include: HERBICIDE USE AND NOMENCLATURE INDEX, a 185-page cross reference of herbicide terminology and use; WEED RESEARCH METHODS MANUAL, a handbook of techniques and "how to" for researchers in the field, particularly those involved with establishing new programs; and TROPICAL WEEDS/MALEZAS TROPICALES, a bilingual volume of weed identification with 150 full color plates of economically important tropical weeds.

Published by International Plant Protection center, Oregon State University, Corvallis, Oregon 97331 USA

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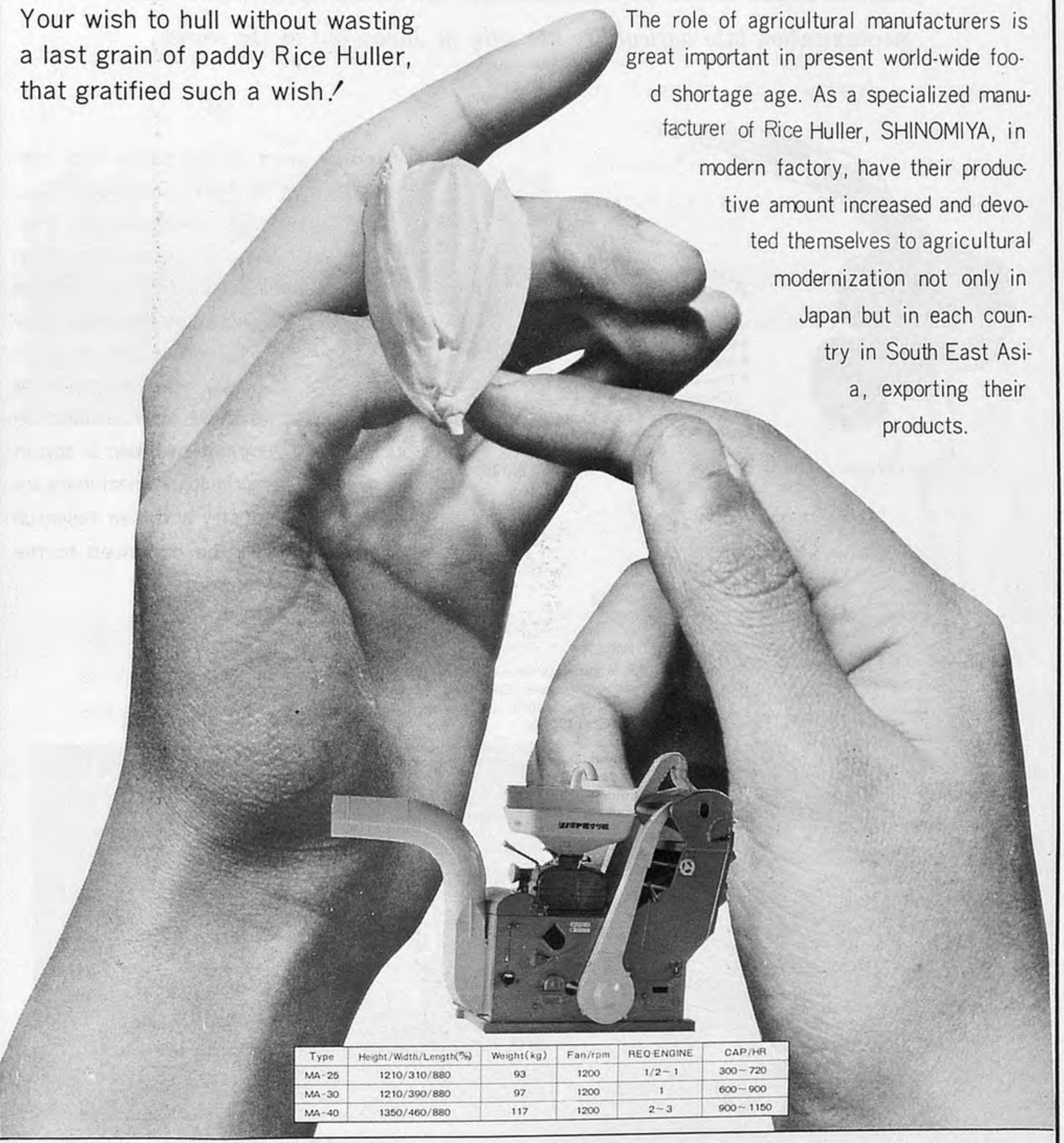

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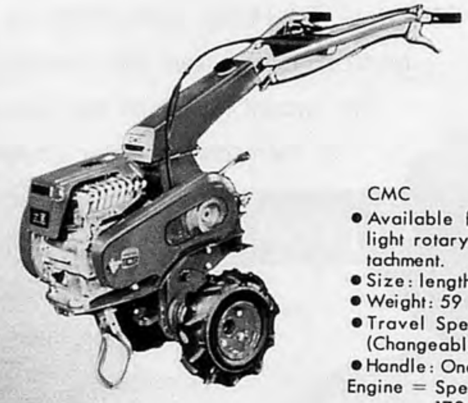

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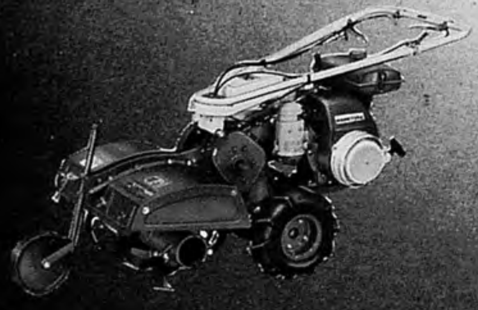

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MRD-180

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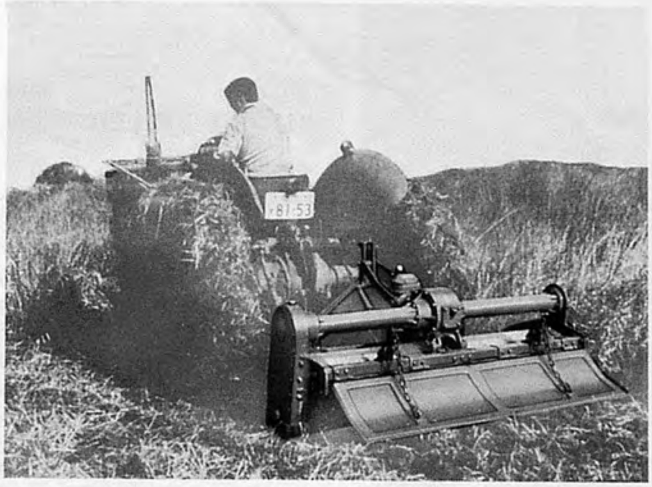

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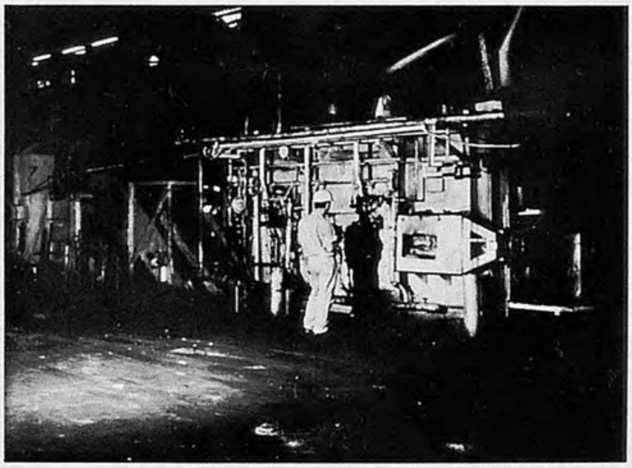

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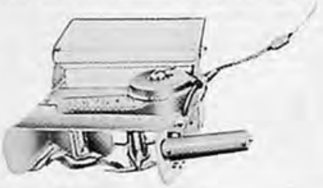
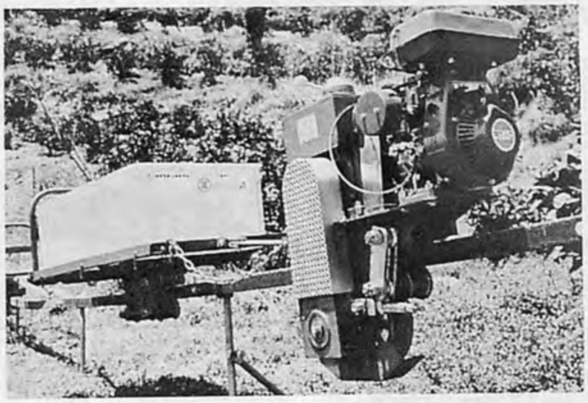


Revolution at steep slope land

Monorail MH-110 Type



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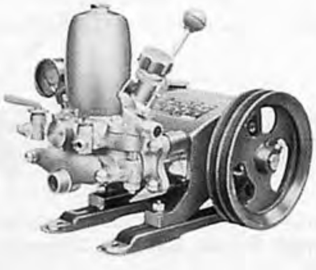

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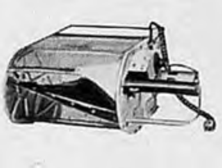

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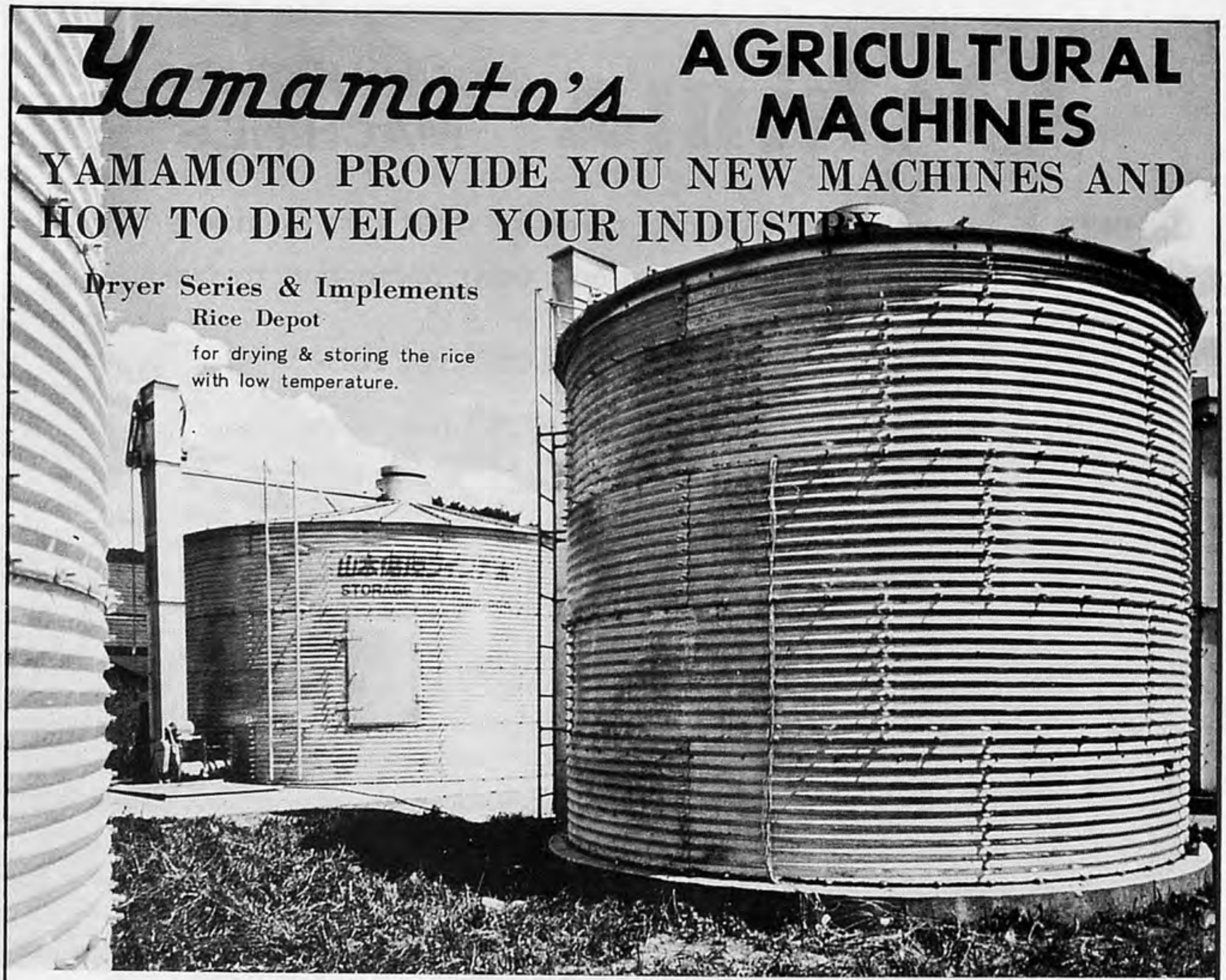
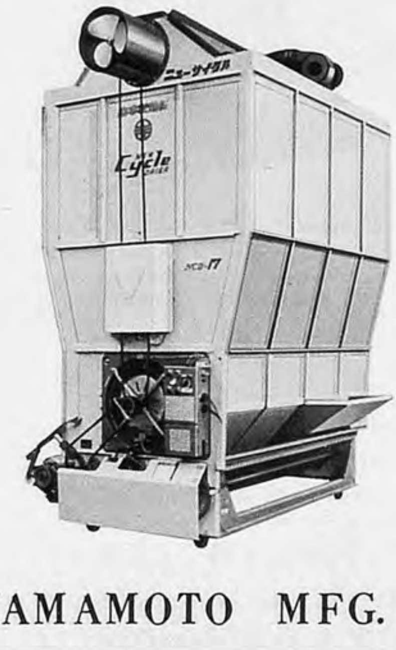
Weight: 8 kg

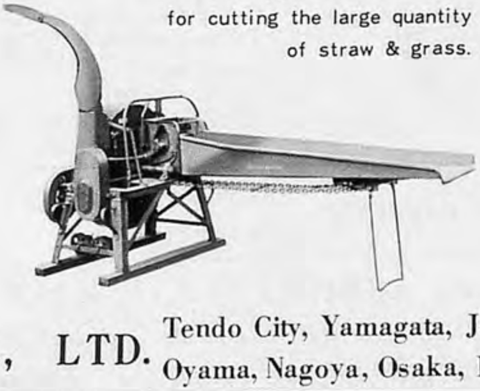
Features of POWER SPRAYER US-34
Weight: 15.0 kg
Maximum Pressure: 35 kg/cm²
Suction capacity: 34 ℓ/1000RPM

For further information, write to:

ARIMITSU INDUSTRY CO., LTD.
No. 3-21, 2-chome, Fukaekita, Higashinari-ku, Osaka, Japan
Cable Address: "ARIMITIND OSAKA"


STORAGE


ニューサイクル
Cycle
MCD-17



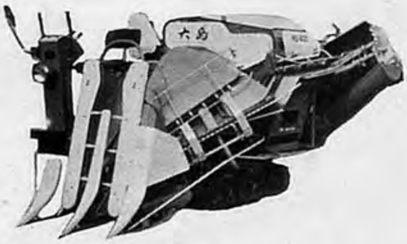
Oshima AGRICULTURAL MACHINES

OSHIMA is the only manifacturing company that can provide you with machines which cover all the operations, from harvesting to hulling.

〈Combine harvester series〉

The Best combine Works Under Any Condition!

- * Unnecesity for hand harvesting, having placed harvesting mechanism at front part.
- * Excellent threshing and separating by work of threshing mechanism as well as heart of combine.
- * Easy operation with all driving equipments around drivers' seat.
- * Adjustable range cutting height 600-1200 m/m by free operating lever.
- * Two outlets with safety device into paddy bags.
- * Light movement even in puddy field for low ground contact pressure.



model RS-600
Engine=7~9HP
Cutting wide=650mm 2row cotting
Efficiency=80~120minutes/10ares

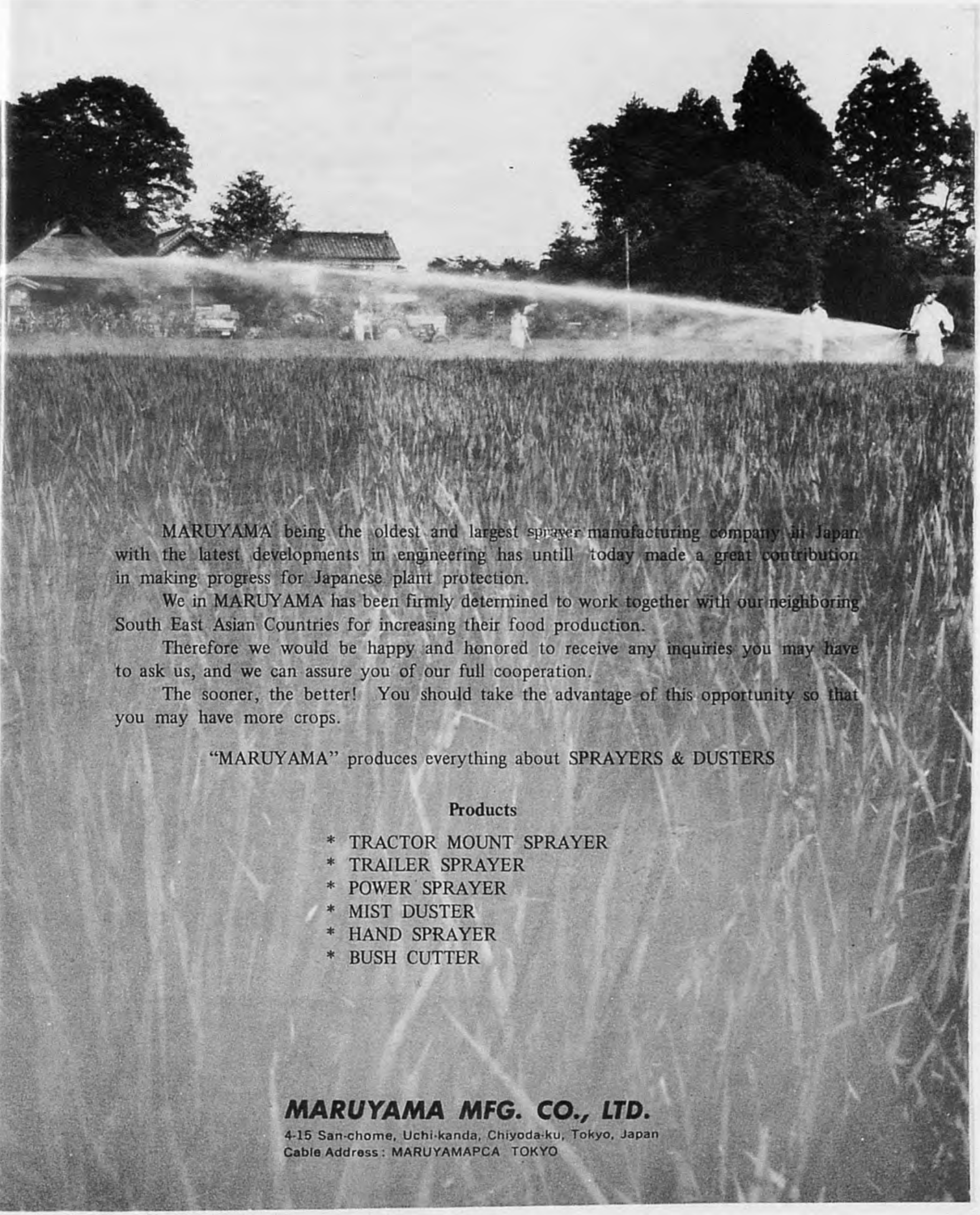
model RS-701
Engine=8~11HP
Cutting wide=700mm 2row cutting
Efficiency=60~90minutes/10ares

model RS-771
Engine=10~13HP
Cutting wide=700mm 2row cutting
Efficiency=60~90minutes/10ares

model RC-901
Engine=11~15HP
Cutting wide=900mm 3row cutting
Efficiency=40~70minutes/10ares

OSHIMA'S MACHINES *Combines *Binders *Rice Dryers *Rice Hullers *Power Threshers *Power Sprayrs *Water Pumps

OSHIMA AGRICULTURAL MACHINERY MFG. CO., LTD.
Head Office : 10-17, Teramachi 3-Chome, Joetsu City, Niigata Pref: Japan
Branch Office : Takada, Yamagata, Tokyo, Osaka, Fukuoka, Asahikawa



FOR YOU

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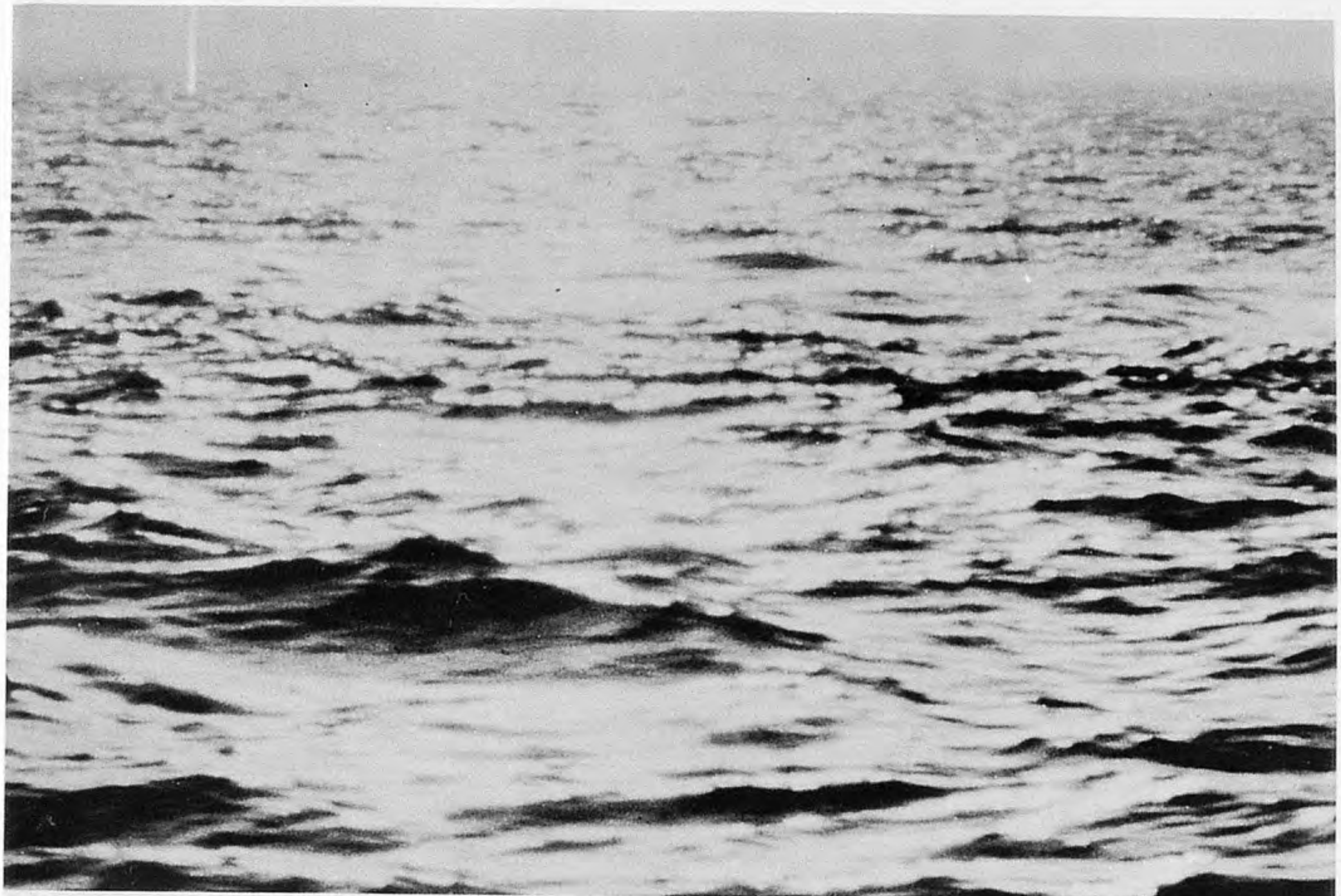
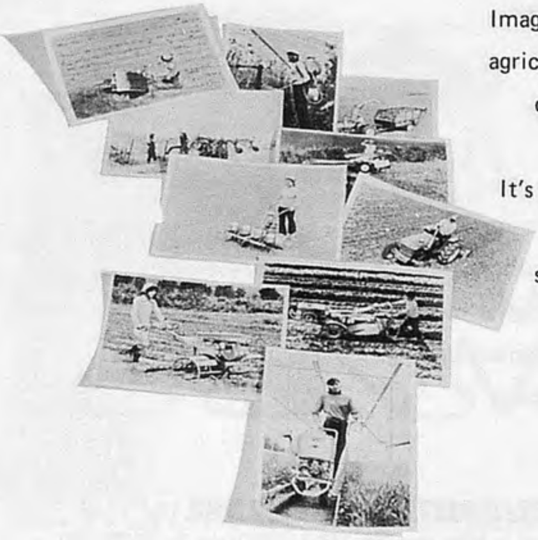
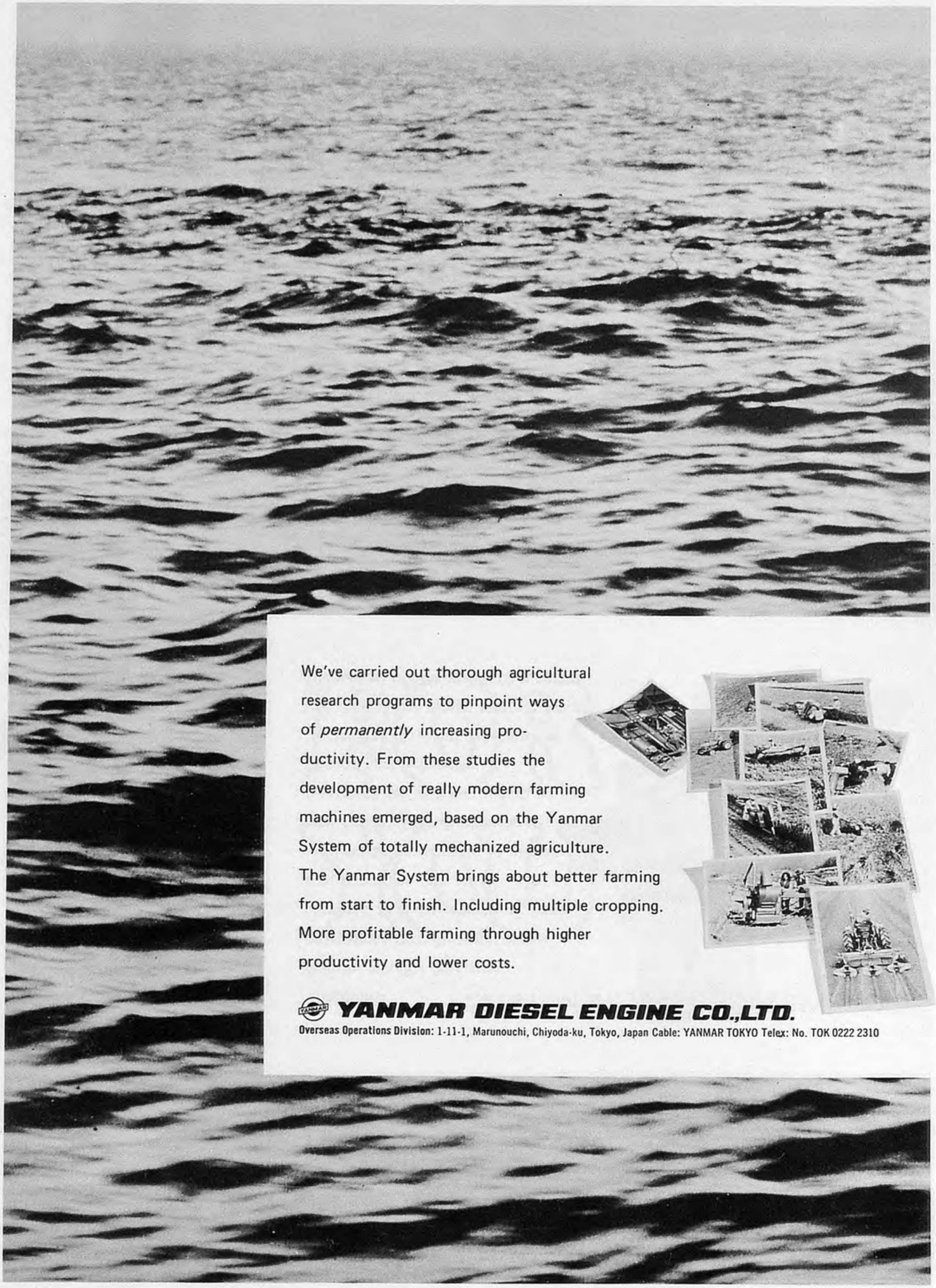
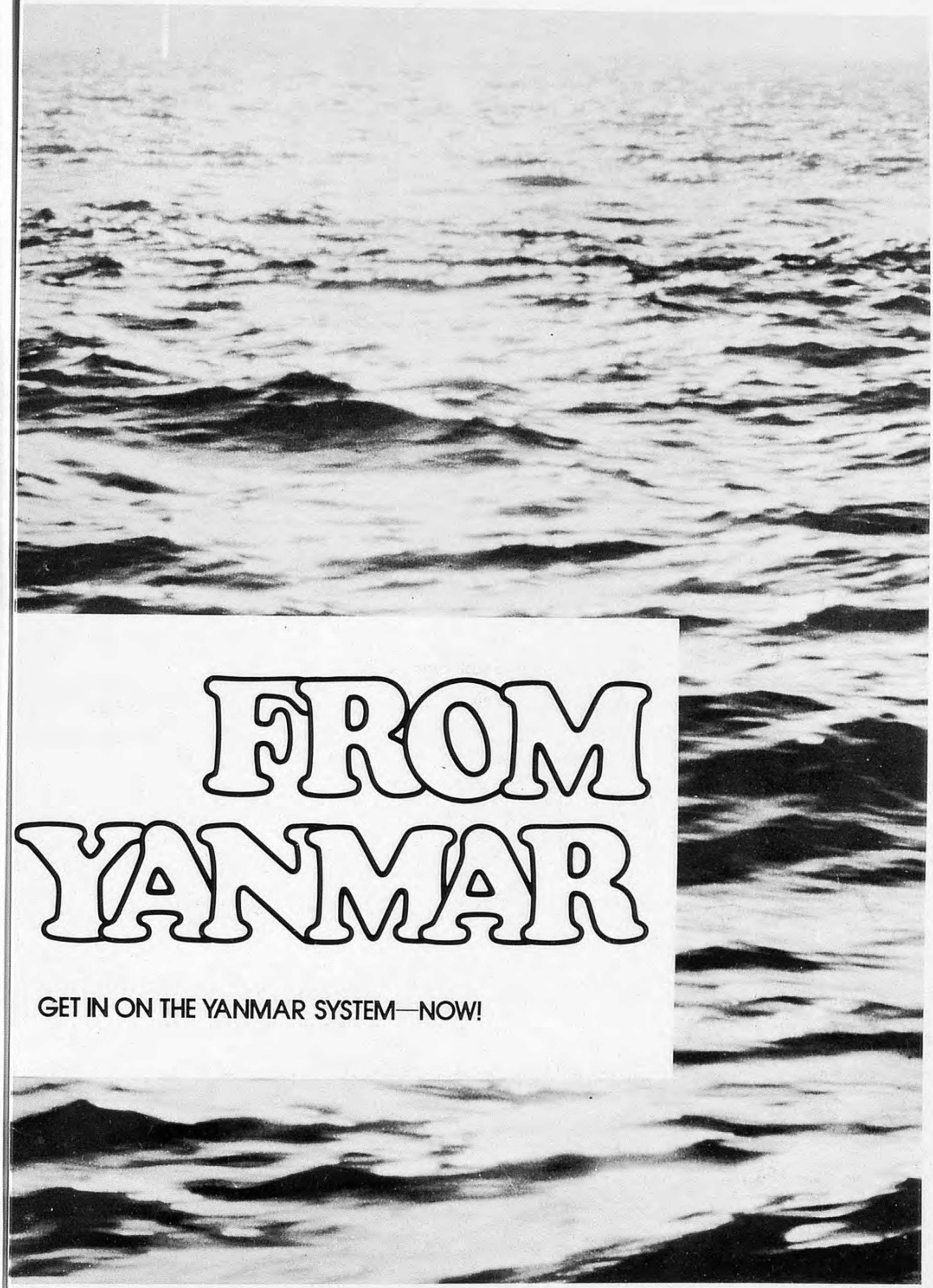




Imagine a complete system of modern agriculture that covers everything: soil conditioning, planting, cultivating, harvesting and storage.

It's no dream. Yanmar has succeeded in developing a completely new system of mechanized agriculture. One that cuts costs to a minimum while at the same time boosting crop yeilds. And satisfying regional farming conditions.

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YANMAR
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