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EDITORIAL

Agricultural Mechanization: A Recurring Issue

It is significant to note that this 1991 Summer issue of AMA carries two interesting articles from four of our contributing editors/cooperators from India and Turkey: Professors R.S. Sidhu and S.S. Grewal (p. 67) and Professors Yusuf Zeren and Alim Isik (p. 63), respectively. Both articles address agricultural mechanization as a recurring issue and highlight the result of almost identical studies undertaken in two different scenarios and two different time frames — with a common conclusion that agricultural mechanization does not replace human labor but rather increases its utility by increased cropping intensity due to farm mechanization and by generating various other employment opportunities.

Professors Sidhu and Grewal examined the issue in the light of the Green Revolution that started in Punjab agriculture in the mid-1960s and concluded that: i) agricultural mechanization is part of the dynamics of agricultural development for improving resource use efficiency and productivity of agricultures; ii) significant increases in production and cropped area can offset the labor-displacing effect of selective mechanization; iii) the cumulative increase in employment would far exceed any on-farm labor displacement; and iv) agricultural diversification through mechanized farming can help increase labor employment and restore ecological balance.

On the other hand, Professors Zeren and Isik attribute to the advent of agricultural mechanization in Turkey that: i) surge in local manufacture of farm machineries, notably tractors; ii) increased use, hence availability of such farm inputs as fertilizer, irrigation water and farm pesticides; and iii) overall increase in agricultural production.

The findings of these professors (their articles are highly recommended for reading) not only confirm graphically and more convincingly what previous editorials of AMA have been saying all along, namely; that public policies in many Third World countries are still reluctant to go for large-scale agricultural mecchanization for fear of social costs of human labor displacement.

To be sure, it is not late on the part of policy-makers in Third World countries to rethink more seriously larger scales of farm mechanization for this might well lend solution to such problems and fears as: i) population explosion which has been forecast to exceed 10 billion by the year 2025; ii) global warming due to eco-system imbalance; and iii) tension among nations.

The AMA is indeed thankful that our contributing editors/cooperators continue to provide articles that can serve as meaningful eye-openers so that policy-makers might see the light about the virtues of agricultural mechanization.

Yoshisuke Kishida
Chief Editor

Tokyo, Japan
June, 1991

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol. 22, No. 3, Summer 1991

A New Rice Harvesting Technology and its Stripper-featured Machine System

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Abstract

The machine system presented in this paper consists of a self-propelled stripper combine harvester and a self-propelled track chassis for transporting the grain sacks off the field and for windrowing the threshed straw with mounted reaper.

The stripper harvester drum type thresher used to thresh the standing rice, the air suction is employed to reduce the grain loss and a pick-up system is equipped for harvesting the lodged crop. The incorporation of the threshed standing unchopped rice straw into the soil was tested both in the field and pot conditions for 3 years in comparison to chopped straw incorporation.

Field test results of stripper performance and whole unchopped straw incorporation to soil are presented along with a description of the advantages of this machine system in the aspects of overall efficiency.

Acknowledgements: This project is financially supported persistently by the Heilongjiang Provincial Government, the Science and Technology Commission of Heilongjiang Province, and Heilongjiang General Bureau of State Farms. This paper is the result of the cooperative effort with Yi-lan Harvester Manufacturing Factory as the manufacturer of the prototype. Valuable suggestions from former chief engineer of Chinese Academy of Agricultural Mechanization Sciences, Senior Engineer Wang Wanjun to the material arrangement and language improvement of this paper are also acknowledged.

Introduction

From the viewpoints of machine performance, straw utilization, the overall efficiency of rice harvesting mechanization and facilitating the subsequent tillage for seed-bed preparation, some of the following shortcomings may be found for each of the existing combines when harvesting rice and the concerned technology:

- High percentage of hulled and broken grain, if the hulled grain reaches 10%, the grain yield will be decreased by 2% (r.t.CC*);
- Relatively poor adaptability to high yield (r.t.CC) and wet crops (r.t.CC but also AFC* to some extent);
- Severe damage to the straw, which renders it unusable as material for by-product production; (r.t.CC and AFC);
- Very complicated mechanisms for transporting the plants before and after cutting, for clipping the plants for threshing, for regulating the depth of feeding (r.t.HFC*);
- Many deep treads left in the field by harvesting machines and transporting machines, burdening the tillage for the seed-bed preparation (r.t.CC and AFC);
- Lower output due to narrow swath (r.t.HFC);
- Lack of grain sack transporting means like truck with track (r.t.HFC).

Following the principle of developing the new harvesting machine based on the agronomic requirements to some extent, and the viewpoint of system analysis, this project aimed to solve the problems mentioned above.

*Abbreviation: r.t. (refer to), CC (Conventional Combine), AFC (Axial-flow Combine), HFC (Head-feed Combine, Japan).

Development of Stripper-featured Machine System and Harvesting Technology

This machine system consists of a self-propelled track stripper and self-propelled track chassis with mounted reaper, plow and rotary tiller.

Self-propelled Track Stripper (Figs. 1 and 2)

It is essentially composed of pick-up (21), stripper-thresher (18), pneumatic conveyer system, rethresher-separator (11) and cross-flow fan for cleaning (10). The plants are deflected by the fingers on chain of the pick-up and gently depressed further by feeding belt (19). Under the action of teeth on threshing drum (17)

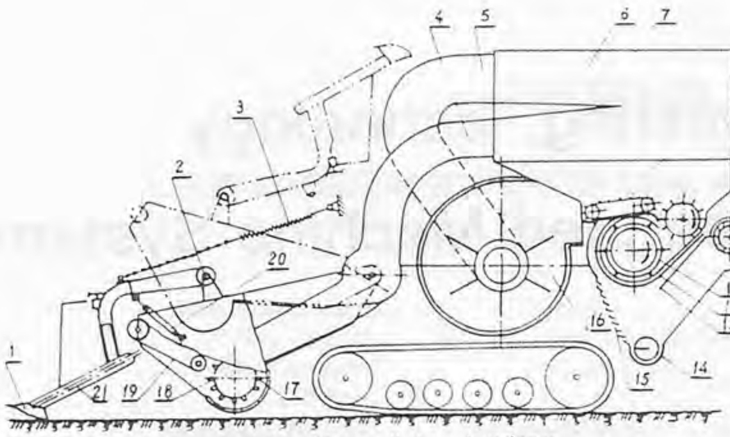

Fig. 1 Schematic diagram of a self-propelled track stripper.


Fig. 2 Self-propelled track rice stripper, front view.

and air suction from pneumatic conveying system the panicles are fed into the thresher. The threshed grain and chaff containing small amount of broken straw are conducted through conduit (4) to the depositing chamber (6) and down to the discharge rotor (9), while air flow along with debris goes through fan (16) to the atmosphere. The mixture of grain and chaff is then conveyed to the axial flow rethresher-separator (11), in which the broken straw of small amount moves axially rearward and is expelled outside by blades on the cylinder. All the grain with debris is separated through the openings of concave grate (12). As it falls to the auger, the debris (light chaff) is cleaned out by a cross air flow exerted by the cross-flow fan (10). The clean grain is elevated and conveyed to sack.

The pick-up mechanism (21) consists of several units, each of which may swing around the axis (2) independently. The skid (1) slightly touches the ground by the compensation spring (3), thus keeping the tip of the lowest finger 5-7 cm above the ground surface for harvesting the lodged crops. In harvesting standing crop they may be lifted in group, to some extent, hydraulically by the cylinder (20). The pick-up device may be turned over to a slant rearward position, leaving room in front of feeding belt for threshing the hand-held plants with head-feeding or reducing the overhang of the machine in its transportation position.

Self-propelled Windrowing-Transportation Track Chassis (WTC) (Fig. 3)

The WTC was refit from a walking tractor, remoulding the final drive and replacing two wheels with metal track. Hydraulically mounted in front is the commercially available reaper which windrows the threshed standing straw or may be used as windrower for rice and wheat. A 9 to 11.2 kW diesel engine is fit at the rear for balancing the weight of the reaper.

Platforms are equipped on sides of the WTC for piling and transporting the grain sacks off the paddy field. When the moldboard plow or rotary tiller is mounted, the WTC is driven in reverse direction, by shifting gear to another position in the final drive. Consquently, this machine system accomplishes the following functions in the field work of rice production:

Grain harvesting;

Standing straw windrowing;

Transporting grain sack off the soft paddy field, leaving no deep treads;

Head-feed threshing as a self-propelled stationary thresher;

Plowing with whole straw incorporated to soil;

Rotary tilling.

Performance of Self-propelled Stripper

Field trial and measurement were performed by the state-authorized Heilongjiang Agricultural Machinery Testing and Evaluation Station and the Agricultural Machinery Testing and Extention Station which is affiliated to Heilongjiang General Bureau of State Farms **(Table 1)**.

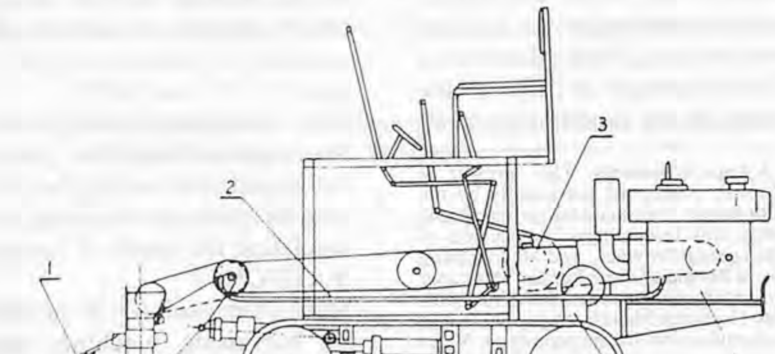

Fig. 3 Self-propelled WTC chassis.

Table 1 Field Trial Results of Stripper Harvester

Year	1988		1987*		
Period of trial	Before hoar frost		Later days in frost period		
Ground speed of machine (m/s)	0.45	0.80	0.45	0.50	1.00
Swath (m)	1.80	1.80	1.80	1.80	1.80
Equivalent feed rate (kg/s)	1.90	3.20	1.20	1.76	3.51
Total grain loss (%)	0.98	2.33	2.66	1.57	1.39
Free grain (%)	0.48	1.23	1.73	1.35	1.13
Unthreshed grain (%)	0.05	0.07	0.52	0.22	0.26
Shoe loss (%)	0.01	0.03	0.09	**	**
Separation loss (%)	0.04	0.43	0.01	**	**
Pneumatic conveying loss (%)	0.39	0.58	0.32	0	0
Cleanliness of grain (%)	95.3	93.8	97.6	—	—
Hulled & broken grain (%)	0.24	0.26	0.28	0.25	0.25
Remainder of MOG# standing on grain	88.8	89.3	88.3	86.0	88.3
Height of panicles from ground (cm)	70	70	60	71.6	71.6
Range of panicle height variation (cm)	33.0	33.0	32.0	41.0	41.0
Grain moisture content (%)	18.7	18.7	13.4	14.5	14.5
MOG moisture content (%)	68.2	68.2	59.6	55.5	55.5
Crop yield (kg/ha)	8 002	8 002	6 395	6 999	6 999

* Field measurement in 1987 was performed by Northeast Agricultural College.
** No rethresher-separator or shoe was fitted in machine.
\# MOG stands for material other than grain.

Technical Features of the Machine System

1. The use of stripping in threshing makes possible to:

- Save the troublesome devices, e.g., those for transporting the plants and clipping the plants for threshing etc., used in HFC, realizing head-feed threshing at the cost of using power-consuming pneumatic conveying system with a big depositing chamber. Moreover, they are simple in construction and trouble-free;
- Increase the swath of machine to 1.80 m, noticeably exceeding that of commercially available HFC. In this respect there is much less limitation to stripper than to HFC;
- Significantly decrease the unthreshed panicles (1-4%) in the grain-chaff mixture, additionally owing to the principle followed in the present research that the plants are fed into the thresher in stretched state with the panicles entering first;
- Considerably decrease the power consumption for threshing. Field and laboratory measurement with electrical-resistance strain gages reveal that the specific power consumption by drum thresher ranged from 0.816-1.40 kW/kg/s of feed rate. Therefore, the total power consumption by machine is not high, even if the pneumatic conveying system is used;
- Have a better adaptibility to high yield crop (8000 kg/ha) dense population (800 panicles/m^2) and wet crops;
- Minimize the amount of MOG passing through the machine whether before the frost period, or in later days of frost period which accounts for only 10.7-14.0%, i.e., the remainder of MOG standings on ground after stripping ranges from 83.9-86.0%, as shown in **Table 1**. The minimal MOG intake has far-reaching implications for rice harvesting: lighten significantly the load of all working units (besides the centrifugal fan) and the potential of machine's trouble, or more clearly, heighten the machine's reliability, which is of great importance for harvesting mechanization in developing countries where due to the less developed manufacturing technology, low reliability is the common embarrassing problem facing the designers and operators.

2. By performing threshing and straw cutting in two separate stages, it is possible to:

- Simplify the stripper and lighten it by setting no cutting and raking mechanisms for windrowing in front of the track.(1) This will evidently result in higher efficiency in grain harvesting — main task of harvesting — and give full play to the superiority of stripping when the straw is planned to be incorporated to soil;
- Windrow the standing straw by the reaper mounted on the WTC, if the straw is to be used as by-product material and fodder. The windrow of threshed rice straw showing all the stems laid in a good (parallel) order, facilitating the manual binding of the straw is illustrated in **Figs. 4** and **5**. It is noted that most of the twigs of the panicles are kept undamaged in threshing. Because the sacks must be moved off the paddy field by some truck, and on which the reaper in any case may be mounted, it is not necessary to provide a truck for windrowing, specially;
- Protect field surface from damage caused by deep treads,

Fig. 4 The stubble and the windrow of the stripped rice straw (right) after the WTC mounted with reaper.

Fig. 5 The closeup of the windrow of the stripped rice straw showing the most of the twigs of panicles being kept undamaged and all stems in parallel order.

owing to the WTC equipped with track. Mechanized rice harvesting practice in China as well as abroad showed that even the half track undercarriage was used in rice combine harvester the deep treads remained unavoidable due to the steering wheels of the harvester and especially the wheels of the truck for transporting the grain off the paddy field. The ideal means for grain transportation in the field is the full track truck. But it is not practical owing to its less versatility in mounting other machines. As for grain sack transportation for a medium or small-sized rice combine harvester, the problem will be a horse of another color. A full track truck, like WTC presented in this paper will be fully justified by its versatility in mounting various machines used in this machine system. Rice growers in Chinese state farms as well as farmers in Europe[2] realize that reduced ground compaction facilitates the crop yield increase and the overall cost reduction, especially if less effort is required for subsequent tillage operation;

- Have a self-propelled track reaper additionally and spontaneously, which itself is a good rice windrower appropriate to soft paddy field. This is equivalent to transferring the cutting device from the combine harvester to the WTC only. But in harvesting practice by conventional combines it is impossible to transfer it to form a windrower.

3. Incorporation of the standing straw to the soil without chopping makes possible to:

- Save the chopping operation and the chopper, which is known as a troublesome working unit (by clogging) in combine;
- Save the power consumption for chopping. The specific power consumption for the combine harvester-mounted chopper is 5.52 kW/kg/s of the feed rate of rice straw according to the field strain gage measurement for East German combine "E-512"[3]. The specific power consumption for typical tractor-powered choppers is between 10.8 and 16.2 kW/kg/s of wheat straw measured by H.G. Gilbertson et al.[4] and 11.1 kW/kg/s by Chinese Agricultural Machinery Evaluation and Testing Station[5]. If the average amount of straw chopped is 10,000 kg/ha and specific fuel consumption of diesel engine is 272 g/kWh, then the fuel savings will be 8.16-12.24 kg/ha for tractor-powered choppers and 4 kg/ha for combine harvester-mounted choppers. Obviously, this is not a negligible amount;
- Provide a favorable condition for practicing the rotation system in tillage and straw disposal which is much sought after in Northeast China. One rotation in this system constitutes 2 or 3 years. In the 1st year for each field: plowing with moldboard plow and the standing straw is directly incorporated into soil as organic fertilizer. In the 2nd year or even 3rd year: rotary tilling after the standing straw is windrowed as by-product material, fodder or fuel. Such an arrangement gives a full consideration of multiple use of rice straw and economically and agronomically based way of tillage. But this rotation practice is based on the availability of stripper harvesting without cutting the straw and the WTC equipped with a track undercarriage which avoids the deep treads impeding the rotary tilling;
- Avoid the trouble of clogging in the plowing of the paddy stubble field by virtue of the fixture of the standing stems to the ground; and
- Have an even distribution of the straw incorporated into the soil by virtue of no displacement of straw. But chopped straw is often poorly spread, especially in windy conditions[4].

4. To clean out the debris from the grain-chaff mixture falling from the rethresher with only the suction air flow instead of the conventional shoe system makes it possible to:

- Omit the sieves, thus simplifying the construction and lightening the machine; and
- Increase the reliability and reduce the vibration of the machine because the sieve would be the only mechanism having the reciprocating motion, if it was put on. (The other reciprocating motion-cutter bar, as previously mentioned, is omitted too). As known to all, these two working units are more likely to have trouble than any rotating mechanisms in the harvesting machine. Such an anticipation has been justified by the machine's field practice. Surely, the machine's high reliability should partly be attributed to the extremely small amount of MOG passing through the machine. In respect of cleaning performance omitting the sieves is also not groundless. Field practices in China reveal that the cleanliness of grain harvested by HFC of the Chinese[6] as well as the Japanese[7] make equipped with sieve-blast shoe system varied in the range of 94.48-98.2% and 93.0-98.5%, respectively, which makes the grain having to be cleaned additionally in post-harvest treatment for attaining the marketable grain standard. Meanwhile, in the stripper-harvester presented in this paper the grain underwent cleaning twice by airflow suction. One occurred in the depositing chamber; the other under the rethresher. That accounts for the considerable grain cleanliness achieved in that stripper-

Fig. 6 The heavily lodged (without an identity of orientation) rice crop sown in broadcasting way was successfully harvested by stripper with the grain loss 1% or so.

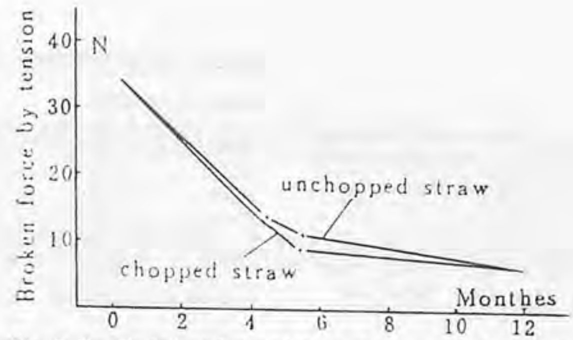

Fig. 7 Tensile failure force of straw changes with the duration of incorporation.

Table 2 Three-year Increments of Nitrogen and Organic Matter in Soil

Item	Treatment	Before incorporation	3rd year after incorporation	Increment in 3 years
Total N (%)	C K *		0.1520	0.0038
	Unchop.	0.1498	0.1631	0.0133
	Chop.		0.1639	0.0141
Avail. N (ppm)	C K *		112	46
	Unchop.	66	126	60
	Chop.		120	54
Organ. matt. (%)	C K *		3.99	0.09
	Unchop.	3.94	4.14	0.20
	Chop.		4.18	0.24

* r.t. "check," i.e., control group.

harvester. Since it is so, it would be better to omit the sieves in the cleaning system.

5. The floating pick-up device specially developed for this stripper-harvester makes the machine possible to:

- Have a quality harvest of heavily lodged crop, (with less than 2.0% total grain loss) which consists of no minor part of rice crop in certain areas as well as years in China, and
- Improve the adaptability to various crop conditions. (**Fig. 6**).

Incorporation of Standing Whole Straw (Unchopped) into the Soil

To incorporate whole straw or green manure crop into the soil is a common practice in some rice growing areas of south China. They are easily decayed due to high temperature and high moisture content. But the result of such a practice in northeast China is quite uncertain. Prior research[8-10] on straw incorporation reveal different effects of acetic acid or toxic gas resulting from straw on germination, plant growth and crop yield, and held different positions toward the seriousness of these effects.

It is reasonable to assume that the transplanted rice plant which is a dominant practice in China may be stronger than the seedling by direct sowing to withstand the effect from the acetic acid produced by concentrated incorporated straw. Obviously, if the positive results are obtained, the standing straw after stripping may be directly incorporated into the soil, thus significantly simplifying the straw disposal technology and facilitate the practice of ecological farming. The physical and chemical properties of the soil incorporated with all and chopped straw and rice yield are investigated in tis connection. The whole straw with the applied amount of 3000-6000 kg/ha was incorporated into the soil by plowing. The paddy field flooded with thin layer of water was harrowed and planed by the related machines trailed by a two-wheel tractor on which the drive wheels are replaced with metal wheels fitted with spade lugs.

The change in straw strength, which is characterized by tensile failure force for single straw, is used to express the decay process during the first year after the incorporation. It can be seen that the two curves in **Fig. 7** are quite close to each other. This suggests that there exists an extremely small difference in straw decomposition between whole and chopped straw incorporation.

Table 2 shows the 3-year increments of total nitrogen N, available N and organic matter in soil incorporated with straw, either chopped or unchopped, are remarkably higher than those of the control group. But the difference in those increments between unchopped and chopped straw incorporation are not significant.

From **Tables 3** and **4** it can be seen that there is no significant difference in grain and straw yields in the first year between whole straw and chopped straw incorporation. Because in the second or third year the incorporated straw should eventually be decayed and then they not only will cause no harm but also favorable effect on rice growing. Therefore, only the first year yield is checked. The test of hypothesis (no significance in difference) shows that the ratio of variation is $F = 0.494$ for grain yield and $F = 0.074$ for straw yeild. Both of them are much less than $F_{0.10} = 2.473$. The hypothesis should be accepted.

The pot experiment reveals that whole straw incorporation into the soil should be accompanied with the application of urea which supplies sufficient N for microorgan-

Table 3 Grain and Straw Yields of Rice in the First Year after Incorporation

Treatment	Grain (g/m^2)		Straw (g/m^2)	
	$\overline{X}$	$X_{\sigma n-1}$	$\overline{X}$	$X_{\sigma n-1}$
Whole straw	765.7	61.2	539.9	90.7
Chopped straw	747.3	48.7	530.8	73.8
C K	742.4	70.1	546.2	128

Table 4 Test of Hypothesis of Grain and Straw Yields

Source of variation		Sum of squares	Degree of freedom	Mean square	F#
Inter-group	Grain	3 631	2	1 815	0.494
	Straw	1 473		736.5	0.074
Inner-group	Grain	121 249	33	3 674	
	Straw	330 465		10 014	$F_{0.10} = 2.437$
Total	Grain	124 880	35		
	Straw	331 938			

Ratio of variations.

isms and plant nutrition needs.

In short, incorporating stripped rice straw into the soil presents no serious problems both biological and technical in Northeast China, but the effect on it caused by different ways of rice sowing and climatic conditions will need to be checked over a period of years.

Conclusions

1. Total grain loss ranges from 0.975% to 2.33%, varying with ground speed of the machine.
2. Intact grain with negligible damage is obtained and meets the seed requirements.
3. The stem with slightly damaged leaves can be obtained in good order without disturbance that are suitable for the material for bags and rope.
4. The stripper has a good adaptability to:
   - high yielding rice with a high plant population (8 000 kg/ha and 800 panicles/m^2);
   - rice with high moisture content (18.70% for grain and 68.20% for stem and leave) as well as to dry crop after the frost falls with a relatively decreased ground speed of machine;
   - lodged crop harvesting with multiple orientations of lodging.
5. Compared with the head-feed rice combine (Japan), machine construction has been somewhat simplified. Its working width broadened and more may be done, if needed, thus opening a new way to increase its productive capacity.
6. The minimal amount of MOG passing through the machine whether before the frost or in later days of frost period significantly lightens the load of all working units and lower the potential of machine's trouble.
7. The machine system provides a possibility to incorporate standing stem into soil without chopping, thus saving the chopping operation, the chopper, power consumption and avoiding the clogging of plow by straw.
8. Incorporation of standing, unchopped stem to soil can rival that of chopped one in regard to the decomposition of straw and improvement of nutrient content in soil and rice yield in the first year.
9. Self-propelled track chassis for windrowing straw and transporting grain sacks protects ground surface from damage by deep treads and assures stripper to work without stopping for waiting for sack.

Therefore, the technology and machine system exhibited its superiority in performance, facilitation of straw utilization, and overall efficiency of harvesting mechanization. However, it has the following shortcomings:

1. The pneumatic conveying system is power-consuming (but the specific power consumption of the machine is not higher than the average) and has a huge depositing chamber (but the whole system is trouble-free as a reward).
2. Additional operation for windrowing is needed, as the straw is to be used as by-product material.

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Grain Losses in Wheat Harvested by Tractor Front-mounted Reaper-windrower

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Abstract

The field investigations were carried out to study and evaluate grain losses in wheat crop harvested by Sayyed reaper-windrower at two sites during 1986. The machine harvesting was also compared with the conventional method of harvesting.

At Malir Farm, the total grain losses by machine harvesting averaged 41.1 kg/ha whereas by manual harvesting losses averaged 84.9 kg/ha. Grain losses in manual harvesting were 51.58% higher than machine harvesting.

At Latif Farm, by machine reaping, grain losses averaged 48.0 kg/ha. whereas by manual harvesting losses averaged 139.6 kg/ha. Grain losses in manual harvesting were 65.6% more than machine harvesting.

At Malir Farm, the labour requirements for machine and manual harvesting and bundling were 31.1 and 85.8 man-hours/ha, respectively. The manual harvesting man-hours /ha were 64.0% more than machine harvesting.

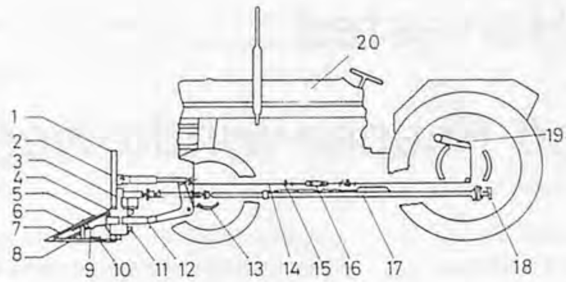
As for the Latif Farm the labour requirements for machine and manual harvesting wre 28.5 and 88.6 man-hours/ha. For the manual harvesting the man-hours/ha were 67.8% higher than machine harvesting.

It was concluded that the use of reaper-windrowers would contribute in the mechanization of harvesting cereal crops and help in increasing profits and productivity of the farmers.

Introduction

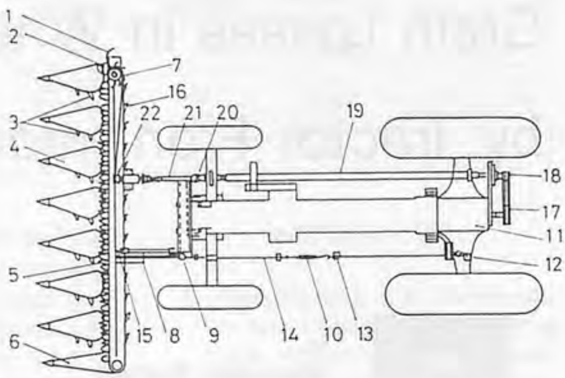
Harvesting of crop is the most labour consuming field operation. Efficient harvesting is a main factor that reduces grain losses. Due to rapid urbanization and migration of farm labour to cities a big vaccum has been created in the supply and demand ratio of farm labour. This paucity of labour force has been forcing the farmers to go for mechanization. The cost ratio of manual harvesting and mechanized harvesting is 3:1. At the peak harvest, scarcity and unavailability of labour increases labour costs with the result that the farmers now pay an exorbitant amount of US $ 37 per hectare of wheat harvest (Altaf and Chaudhry). On the other hand, due to change in weather, late harvesting of wheat results in considerable damage to the standing crop in the field.

Fast and efficient method of wheat harvesting is the immediate need of the farmers. At such stage, when timeliness of harvesting operation is the main criterion, the



1	super structure	11	lugs and flat belt
2	upper telescopic link	12	lover link
3	B-grove pulley	13	universal joint
4	flat pulley	14	wire rope
5	deflector	15	u-clamp
6	star wheel	16	turn buckle
7	header shield	17	main drive shaft
8	header	18	counter pulley
9	spring	19	tractor link
10	cutter bar & guard	20	tractor

Fig. 1 Side View of Sayyed reaper windrower.



1	deflector	12	tractor link
2	cutter	13	u-clamp
3	star wheel	14	wire rope
4	shield	15	upper link
5	guard	16	belt and lugs
6	end header	17	pto pulley
7	flat pulley	18	counter pulley
8	lover link	19	propller shaft
9	shackle	20	universal joint
10	turn buckle	21	telescopic shoft
11	tractor	22	cam pully

Fig. 2 Top view of Sayyed reaper windrower.

use of reaper-windrower for harvesting of wheat crop should be most appropriate.

Hence the study of mechanized harvesting by using the tractor power take off driven reaper-windrower was undertaken in order to determine grain losses relative to conventional harvesting system.

Experimental Procedure

The field experiments were conducted at two sites: site-I was selected at Malir Farm and site-II at Latif Farm of the Sind Agriculture University, Tandojam Experimental Farm during 1986.

The machineries and equipment used in the research work were: Massey Ferguson-135 tractor, Sayyed reaper-windrower, one meter square frame; polythene bags (large and small); sickle, polythene sheet (12 meters long); electronic balance; and camera.

Machines

The main parts of the Sayyed reaper-windower are shown in **Figs. 1** and **2**. **Figs. 3, 4, 5, 6, 7** and **8** also show the machine and its parts. The Sayyed reaper-

Fig. 3 Front view of Sayyed reaper windrower.

Fig. 4 Side view of Sayyed reaper windrower.

Fig. 5 Closeup of crop lifter, star wheel, knife and fingers.

Fig. 6 Rear view of Sayyed reaper windrower.

Fig. 7 Driving mechanism of Sayyed reaper windrower.

Fig. 8 Driving mechanism of Sayyed reaper windrower.

windrower is a tractor front-mounted harvesting and windrowing machine. It has a 2-meter long cutter bar. It cuts the crop and lays it in a windrow which can be easily picked up by the farm labourers. The harvested crop plants are held in position by pressure springs and guided by the star wheels to the lugged conveyor belt. The harvested crop is conveyed in vertical position until discharged.

Grain Losses

Grain losses are loss of profits. The loss of grain in terms of profit means additional harvesting costs. The acceptable minimum grain loss is between 1-2%. It is possible with the present harvesting system to reduce grain losses with proper setting and timely harvesting.

Preharvest Loss

Preharvest loss is defined as the weight of grains fallen on the ground. Wheat grains and earheads fallen on the ground were collected from seven randomly selected samples from one square-meter area spot. The grains so collected and weighed are denoted as Wgo. The frame of one square meter was used for collecting the shattered grains and earheads. **Fig. 9** shows the collection of grains and earheads fallen on the ground.

Cutter Bar Loss (Header Loss)

Cutter bar loss is defined as the loss owing to cutter bar during reaping. The cutter bar loss was measured by placing one square-meter frame at seven randomly selected spots on a reaped strip for collecting the total grains shatters and cut earheads enclosed within the frame (**Fig. 10** and **11**) which were cleaned and weighed and denoted as W_{g1} and W_{g2}, respectively.

The cutter bar uncut loss was also determined by harvesting the uncut crop from seven randomly-selected spots by using one square meter frame. The crop so obtained was threshed manually and the weight of the clean grain was recorded as W_{g3}.

Fig. 9 Determination of preharvest grain loss.

Fig. 10 Collection of grains and earheads owing to cutter bar loss.

Fig. 11 Collection of grains and earheads owing to cutter bar loss.

Fig. 12 Laying out polythene sheet to determine conveying loss.

Fig. 13 Wheat windrow is conveyed on to the polythene sheet.

Fig. 14 Collection of loose grains and earheads fallen onto the polythene sheet to determine conveying loss.

Fig. 15 Determination of sickle loss.

The averge sum of W_{g1}, W_{g2} and W_{g3} was taken as W_{gt} and the cutter bar loss (H) was obtained as follows:

$$H = \frac{W_{gt} - W_{go}}{Y_g} \times 100$$

where,

W_{gt} = Cutter bar loss, (g/m^2)
W_{go} = Preharvest loss, (g/m^2)
Y_g = Crop yield, (g/m^2)

Conveying Loss

A 12-meter long polythene sheet was placed along side of the wheat to be harvested. After reaping with the machine, the crop windrowed on the sheet was taken away. The shattered grains, fallen on the sheet were, collected and weighed from one square meter area randomly selected at seven different places from each test plot at both sites. The method of determining the conveying loss is shown in **Figs. 10**, **11**, **12** and **14**.

Manual Harvesting Loss

Manual harvesting using hand sickle was carried out in the same fields on the same day (**Fig. 15**). The quantity of grains fallen in each unit operation was deter-

Table 1 Crop Yield per Hectare of Test Plots

Sample	Malir Farm		Latif Farm	
	g/m^2	t/ha	g/m^2	t/ha
1	296	2.96	353.2	3.53
2	411.6	4.12	326	3.26
3	478.5	4.79	472.2	4.72
Average		3.95		3.84

Table 2 Grain-straw Ratio of Test Plots

Sample	Malir Farm			Latif Farm		
	Weight of grain g/m^2	Weight of straw g/m^2	Grain straw ratio	Weight of grain g/m^2	Weight of straw g/m^2	Grain straw ratio
1	296	469	1:1.6	353.2	599.5	1:1.7
2	411.6	634.1	1:1.5	326	473.3	1:1.4
3	478.5	573.9	1:1.1	472.2	664.1	1:1.4
Average			1:1.4			1:1.5

mined as follows.

Preharvest loss:

H_o (%) = $(W_{go}/Y_g) \times 100$

Sickle loss:

Sic (%) = $(W_1 - W_{go}/Y_g) \times 100$

where,

W_{go} = Grain loss due to natural action (g/m^2)

Y_g = Crop yield (g/m^2)

W_1 = Grains and ears fallen on ground due to sickle cutting (g/m^2)

Labour Requirements

The man-hours required for machine and manual harvesting during the test were recorded.

Results and Discussion

Grain losses vary considerably according to the variety of the crop, ripening stage, condition of crop, harvest time, field and harvesting pattern.

Table 1 presents data regarding the crop yield and **Table 2** shows the grain straw ratio of the experimental field. On average, the crop yield and grain straw ratio at both sites was nearly similar.

Table 3 Grain Losses of Sayyed Reaper-windrower and Manual Harvesting (Unit: g/m^2)

Replications	Machine reaping-windrowing					Manual harvesting		
	Shatter	Uncut	Cutter bar	Conveying	Total	Shatter	Sickle	Total
Malir Farm								
1	0	1.2	0	0.2	1.4	0	3.60	3.60
2	0.1	0.4	0.2	1.1	1.8	0.1	17.74	17.84
3	0.2	1.8	0.2	0.6	2.8	0.2	2.00	2.20
4	0	7.3	0.9	0.5	3.4	0	18.30	18.30
5	0.1	0	0.1	1.1	8.5	0.1	0.80	0.90
6	0.2	5.4	2.7	0.4	8.7	0.2	4.20	4.40
7	0.1	1.5	0	0.6	2.2	0.1	2.65	2.75
Average	0.1	2.63	0.68	0.68	4.09	0.1	8.47	8.57
Latif Farm								
1	0.2	0.5	0.3	0	1.0	0.2	2.50	2.70
2	0.3	1.7	0.5	0.5	3.0	0.3	4.31	4.61
3	0.1	2.0	0.4	0.8	3.3	0.1	18.90	19.00
4	0.2	8.1	1.1	1.3	10.7	0.2	2.12	2.42
5	0.3	5.6	3.1	0.7	9.7	0.3	3.30	3.50
6	0.2	1.8	0.3	0.9	3.2	0.2	17.91	18.11
7	0.1	1.5	0.4	0.7	2.7	0.1	4.52	4.62
Average	0.2	3.02	0.87	0.7	4.79	0.2	7.65	7.85

Table 4 Losses of Grain by Reaper-windrower and Manual Harvesting (Unit: %)

Site	Machine reaping					Manual reaping			Crop yield kg/ha
	Shatter (pre-harvest)	Uncut	Cutter bar	Conveying	Total	Shatter (pre-harvest)	Sickle	Total	
Malir Farm	0.03	0.67	0.17	0.16	1.03	0.03	2.14	2.17	3950
Latif Farm	0.07	0.79	0.31	0.29	1.46	0.07	4.18	4.25	3840

Grain Losses

The grain losses of Sayyed reaper-windrower and manual harvesting are shown in **Tables 3** and **4**. At Malir Farm, the grain losses by Sayyed reaper-windrower as shatter, uncut, cutter bar and conveying losses varied from 0-0.2, 0.4-7.30, 0-2.7, 0.2-1.1 grams per square meter. On average, the shatter, uncut, cutter bar and conveying grain losses were 0.1, 2.63, 0.68 grams per square meter, respectively. The total grain losses varied from 1.40-8.70 grams per m^2. On average, the total grain losses were 4.09 grams per square meter. The average grain losses were 1.03% of the crop yield. The results are in close agreement with the findings of Zafarullah (1985), Garg and Sharma (1984) and Khawaja and Choudhry (1980).

On the same farm, the grain losses by harvesting the crop manually for shattering loss and sickle loss varied from 0-0.2, 0.8-18.30 grams per square meter, respectively. On the average, shatter and sickle grain losses were 0.1 and 8.47 grams per square meter, respectively. The total grain loss by manual harvesting was 8.57 grams per square meter. The average grain losses were 2.17% of crop yield. These findings are in close agreement of the findings of Zafarullah (1985).

At Latif Farm, the grain losses

with the use of Sayyed reaper-windrower in the form of shatter loss, uncut loss, cutter bar loss and conveying loss varied from 0.1-0.3, 0.5-3.1, 0.3-3.1, 0-1.3 grams per square meter, respectively. On the average, the grain losses for shattering, uncut, cutter bar and conveying were to 0.2, 3.02, .87 and 0.7 grams per square meter, respectively. The total grain losses observed were 4.79 grams per square meter. The grain losses were 1.46% of crop yield. The results are in close agreement with the findings of Devani and Pandey (1985).

On the same farm, in harvesting the crop manually, the grain losses as shatter and sickle varied from 0.1-0.3, 2.12-18.90 grams per square meter, respectively. On the average, shatter and sickle grain losses 0.2 and 7.65 grams per square meter, respectively. The total grain loss was 7.85 grams per square meter. The grain losses were 4.25% of crop yield. The findings are in close agreement with the work of Iqbal et al. (1980).

Grain losses by harvesting wheat with Sayyed reaper-windrower and manual harvesting are also given in **Table 5** and **Fig. 16**.

At Malir Farm, the total grain losses by using the Sayyed reaper-windrower varied from 14 kg/ha to 87 kg/ha. On the average, the total grain loss by machine use was 41.1 kg/ha. The total grain losses by manual harvesting of crop varied from 8 to 183 kg/ha. On the average, the total grain loss by harvesting the crop manually was 85 kg/ha.

At Latif Farm, by using the Sayyed reaper-windrower, the total grain losses varied from 10 to 107 kg/ha. On the average, grain losses were 48 kg/ha. By harvesting the wheat manually, the grain losses varied from 93 kg/ha to 197 kg/ha. On the average, grain losses by manual harvesting were 139.60 kg/ha.

Table 5 Total Grain Losses by Machine and Manual Reaping Sistem

Falir Farm				Latif Farm			
Machine reaping		Manual reaping		Machine reaping		Manual reaping	
g/m^2	kg/ha	g/m^2	kg/ha	g/m^2	kg/ha	g/m^2	kg/ha
1.40	14.0	3.6	36	1.0	10.0	14.50	145.0
1.80	18.0	17.74	177.4	3.0	30.0	9.30	93.0
2.80	28.0	2.00	20.0	3.3	33.0	15.10	151.0
3.40	34.0	18.30	183.0	10.7	107.0	19.70	197.0
8.50	85.0	0.80	8.0	9.7	97.0	11.20	122.0
8.70	87.0			3.2	32.0		
2.20	22.0			2.7	27.0		
Avr.	41.1		84.88		48.0		139.60

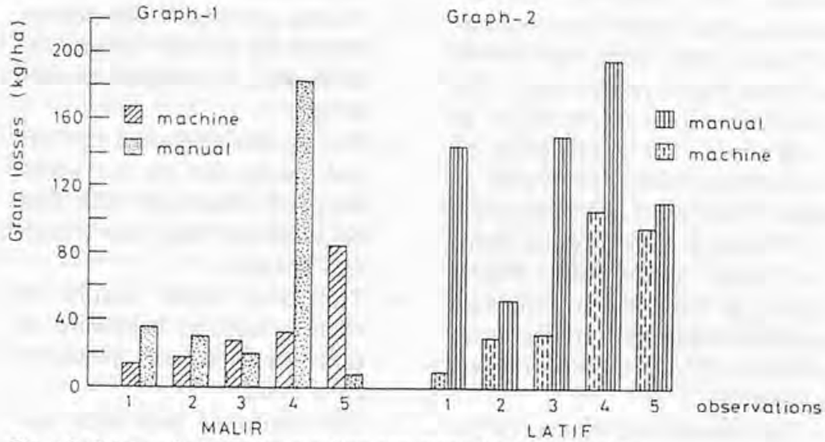


Fig. 16 Total grain losses by machine and manual reaping systems.

Labour Requirements

Table 6 shows the labour requirements for harvesting wheat by Sayyed reaper-windrower and manual harvesting.

At Malir Farm, the machine reaping operation required 3.8 man-hours/ha and 27.1 man-hours/ha for gathering and bundling operations. The manual harvesting took 64.6 man-hours/ha and 21.2 man-hours/ha for gathering and bundling operations. the machine reaping and gathering and bundling operations needed a total of 31.1 man-hours/ha, whereas the manual reaping and gathering and bundling operations required a total of 85.8 man-hours/ha. The results of manual harvesting labour requirements are in agreement with the findings of Zafarullah (1985).

At Latif Farm, the machine harvesting operation required 4 man-hours/ha and gathering and bundling operation took 24.5 man-hours/ha. The manual harvesting required 62.5 man-hours/ha and gathring and bundling operations took 22.1 man-hours/ha. Harvesting by Sayyed reaper-windrower and gathering and bundling required 28.5 man-hours/ha, whereas manual harvesting and gathering and bun-

Table 6 Labour Requirements of Wheat Harvesting

(Unit: man-h/ha)

Reaping system and operations	Malir Farm	Latif Farm
Machine reaping		
i) Reaping	3.8	4.0
ii) Gathering and bundling	27.3	24.5
	31.1	28.5
Manual reaping		
i) Reaping	64.6	62.5
ii) Gathering and bundling	21.2	22.1
	85.8	88.6

dling needed 88.6 man-hours per hectare. The findings of manual harvesting are also in agreement with the findings of Zafarullah (1985, 1986).

Conclusions and Recommendations

The total harvesting losses by using the Sayyed reaper-windrower at Malir Farm and Latif Farm were 1.03% and 1.46% of grain yield, respectively. The grain losses were 0.13% higher at Latif Farm. The grain losses by manual harvesting of wheat at Malir Farm and Latif Farm were 2.17% and 4.25% of grain yield. The grain losses were 2.08% higher at Latif Farm. The low machine losses indicate the efectiveness of the Sayyed reaper-windrower.

The labour requirements by the use of Sayyed reaper-windrower were 60.4 man-hours/ha at Malir Farm and 58.5 man-hours/ha at Latif Farm as compared to manual harvesting of wheat. However, the gathering and bundling operations required nearly the same man-hours/ha at both locations. Thus Sayyed reaper-windrower can eliminate the peak demand of labour during the harvesting season.

Suggestions

After testing the Sayyed reaper-windrower in Pavan wheat at two locations at different crop moisture levels, the following suggestions are made:

1. An adjustable deflector at the right and between the conveyor belt should be provided for adequate and proper laying of windrower.
2. Double grooved V-belt pulleys should be shifted upward or downward to bring the centers in line.
3. The distance between the left end header and the star wheel should be identical with that between the other star wheels and headers.
4. The crop shield should be slightly inclined backward to take the share of harvested crop load.
5. The conveyor belt with lugs should be made of chains instead of canvas to compensate for the slackness of the converyor belt.
6. The reaper harvesting, plus mechanical threshing method is suitable to save "bhoosa" which is used as an animal feed. Surplus bhoosa fetches a good price to the growers. Hence, the use of reaper-windrower is suggested as compared to combine harvester.

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Design of a Thresher for Locust Bean

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Abstract

The drugery involved in the post harvest processing of the locust bean (*Parkia fillicoidea*), particularly in the shelling of the pods to obtain the seeds for further processing, has resulted in the decline of the local production of food condiments that have this fruit as its main raw material. Studies on the physical characteristics of the fruit conducted include the weight analysis of pod, pulp and seed and the dimensions of the clean seed's height, width and thickness. Specific characteristics of the shell and pulp were also studied.

A sheller was designed using the information from the physical characteristics of the fruit. Results of tests conducted indicated a capacity of 9.52 kg/h of polished and clean seeds at 900 rpm and a shelling efficiency of 100%

Introduction

The economic situation in many developing countries of the world has made those countries to "look inwards" for the technological development of their food processing industries. In Nigeria a lot of goods have been banned from importation into the country while there is a scarcity of many that are not banned. For decades the production of local condiments has been carried out mainly by the farmers in the savannah zones of the country. The processing is mainly done by women and the main raw material is locust bean.

The production and hence consumption of this local condiment have declined due to the drugery involved in the local processing. A great percentage of the population depends on the locally processed condiment as they cannot afford the purchase of the industrially processed ones. Many also prefer the taste of the local product.

The locust bean fruit consists of bunches of pods which form the edible part of the plant. Each pod contains a yellow pulp which envelopes the thin membrane that covers the brownish-black seed coat. The pulp is edible as it contains a high percent of sucrose. The seed is fermented after cooking to produce the local condiment.

Research work on locust bean has been concentrated on the chemical composition and nutritional value of the fermented seeds (Oyenuga, 1969; Eka, 1980; Odunfa, 1983), while little information is available on the technology of production of the fermented product. It is known that the locust bean contains 39-40% protein, 31-40% oil, 11.7-15.4% cabohydrate (Campbel-Platt, 1980)

The shelling of the locust bean pods and the removal of the pulp to obtain the seeds for fermentation is the most laborious of all the processing steps in the local production of Iru*. At the moment, the shelling is done manually with the splitting of individual pods to remove the seed with the pulp. The pulp is then dissolved in water and washed off. These two processing steps are labour intensive and time consuming. Designing a machine to shell and depulp the locust bean is highly necessary in order to encourage the local producers so that the local production of condiments may not go into extinction.

Preliminary Investigation

An existing cowpea sheller reported by Ige and Ajayi (1979) was used to carry out threshing trials on locust bean. It was found to be inadequate for shelling locust bean. This is because locust bean has peculiar physical characteristics which are different from that of cowpea. The shell of locust bean is fibrous with a tough rim round the longitudinal edge of the pod unlike the cowpea with a brittle shell. The conventional blunt spikes used on the beater of cowpea shellers is, as a result, not adequate to handle locust bean. Sharp knife edge spikes are preferred on the rotating drum.

The weight analysis of the fruit

*Iru is the local terminology for the fermented locust bean seeds.

was carried out to determine the percentage of shell, seeds and pulp by weight in relation to the whole fruit. Fifty pods of the fruit were selected randomly from the sample container and the weight of each pod measured. The seeds and pulp were carefully removed and the weight of the chaff was determined. The pulp from each seed was removed and the weight of the seeds per pod determined. The weight of the pulp was obtained by subtracting the weights of the chaff and seeds from the total weight of pod. **Table 1** gives the weight analysis for the pod.

The dimensions of the seeds in terms of height, width and thickness were obtained by direct measurement using a vernier caliper. Fifty seeds were randomly selected from the seed container. The mean and standard deviation of the dimensions were calculated (**Table 2**). A knowledge of the range of the dimensions was necessary to determine the size of screen needed for separating the seeds.

Design Considerations

The following were proposed for the machine:

1. A design made up of a stationary concave with spikes and a rotating beater containing spikes whose relative movement with those on the concave could effect the threshing of the pods
2. Due to the fibrous and tough characteristics of the rim around the longitudinal edge of the pod, sharp-edged spikes were considered for the central rotating beater in the concave to effect the cutting of the tough rim.
3. A hopper designed to allow the lateral feeding of the pods to make the cutting of the pods possible.
4. A sieve below the beater housing to sieve off the seed containing the pulp and an axial flow fan on the same shaft with the beater to suck out the shell.
5. A polisher with an abrasive surface below the threshing chamber screen to remove the pulp and the thin membrane surrounding the seeds.
6. An arrangement of screen and blower to separate the clean seed from the pulp and other particles.

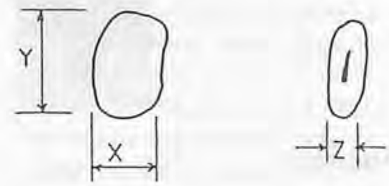
The beater has a tip-to-tip diameter of 23.4 cm while the polisher is of 8 cm diameter.

Table 1 Weight Analysis of Locust Bean Pod from 50 Randomly Selected Pods

Measurement	Chaff (%)	Seeds (%)	Pulp (%)
Mean	39.6	23.9	36.5
Standard deviation	1.26	0.92	1.03

Table 2 Dimensions of Locust Bean Seed from 50 Randomly Selected Seed Samples

	X (mm)	Y (mm)	Z (mm)
Mean	8.1	11.4	4.8
Standard deviation	0.55	0.97	0.63



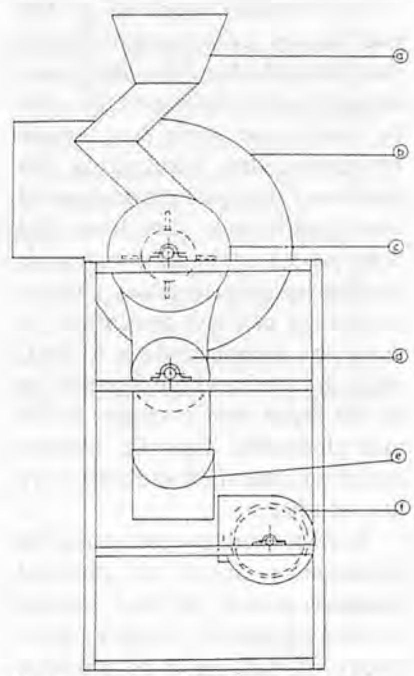


Fig. 1 End view of the sheller: a, hopper; b, trash extraction fan; c, shelling chamber; d, polishing chamber; e, seed retainer; f, blower.

Thresher Performance Test

Fig. 1 shows the end view of the thresher. Threshing tests on the machine were carried out at two moisture levels of the locust bean; these were at 6.41% and 13.31% dry basis. The two moisture levels are the moisture contents of materials in stock. The lower one being that stored in an open container in the laboratory while the other was that stored in a sealed container in the laboratory. The two were kept in the laboratory for about 6 months before the test. Four speed levels of the machine were employed in carrying out the test, the control of the variable speed motor powering the machine being set to obtain the desired speed. A tachometer was used to read the speed of the beater shaft. At a given speed of the beater shaft threshing tests were carried out by feeding 6 pods into the machine per drop every 5 s. Preliminary tests were conducted to determine the range of the feeding rate to prevent choking. The feeding rate was not considered in weight per unit time, as it was difficult to get equal weight of pods to feed into the machine per unit time. There were two replicates for each run and the average of the following were recorded:

i. Weight of shelled seeds at the retainer outlet.
ii. Weight of polished seeds.
iii. Weight of seeds retained in the machine.
iv. Weight of unshelled seeds.

v. Weight of seeds blown out through the suction fan.

vi. Total weight of seeds through the machine.

vii. Time of residence.

The test was repeated for a feeding rate of 12 pods per drop every 5 s. The parameters considered in testing the machine are:

(a) *Polishing efficiency*—The ratio of the weight of polished seeds that pass through the polisher to the total weight of seeds at the outlet of the seed retainer, expressed as a percentage;

(b) *Shelling efficiency*—The ratio of the total weight of seeds shelled to the total weight of seeds fed into the machine expressed as a percentage; and

(c) *Material capacity* (kg/h)—The ratio of the total weight of seed obtained per run to the time of residence.

Results and Discussions

For all the tests carried out on the machine, the speed of the beater affected the performance. The threshing efficiency increased with the speed of the rotating beater. This tended to 100% from a speed of 700 rpm of the beater (**Fig. 2**). At the lowest speed of 300 rpm the threshing efficiency was low for the two feeding rates of 6 and 12 pods per drop of 5 s interval. More materials, particularly chaffs, were retained in the machine at this speed than at higher speed. The extraction fan was not able to develop enough pressure to suck the chaff out of the threshing chamber.

The feeding rate has an effect on the threshing efficiency. The higher feeding rate gave a higher threshing efficiency at higher speed and a lower efficiency at lower speeds. The lower moisture level of 6.4% gave a higher threshing efficiency at the lower beater speeds. The lower the moisture content of the pod, the more brittle the chaffs become and hence the easier it is to thresh and to separate the chaffs from the seeds.

The polishing of the seeds which is the removal of the pulp and the thin membrane covering the seed is done in the polishing chamber. The process is carried out by the abrasive action of the polishing surface and as the seeds rub on each other. The effectiveness of the process has been found to be affected by the quantity of the seeds present in the chamber and the speed of the polishing shaft. The lower the polisher speed, the higher the polishing efficiency (**Fig. 3**). The polishing, being an abrasive process, is time dependent and the lower the speed of the abrasive surface, the more it can act on the seeds and the more the rubbing action of seed against seed. This resulted in higher polishing efficiency.

Higher speeds of the polisher resulted in faster discharge of the seeds through the screen without proper polishing. Less rubbing of seed against seed was also realised at higher speeds of the polisher, hence a lower polishing efficiency. At higher feed rate, more seeds were available in the polishing chamber. This aids the abrasive action that effects the polishing of the seeds, hence a higher polishing efficiency recorded for the higher feed rate (**Fig. 3**).

Generally, the polishing efficiency obtained for this test is low. This is a result of the long period of storage of the locust bean sample. The longer the storage the drier the sample and, hence the stronger the thin membrane is bound to the seed making it

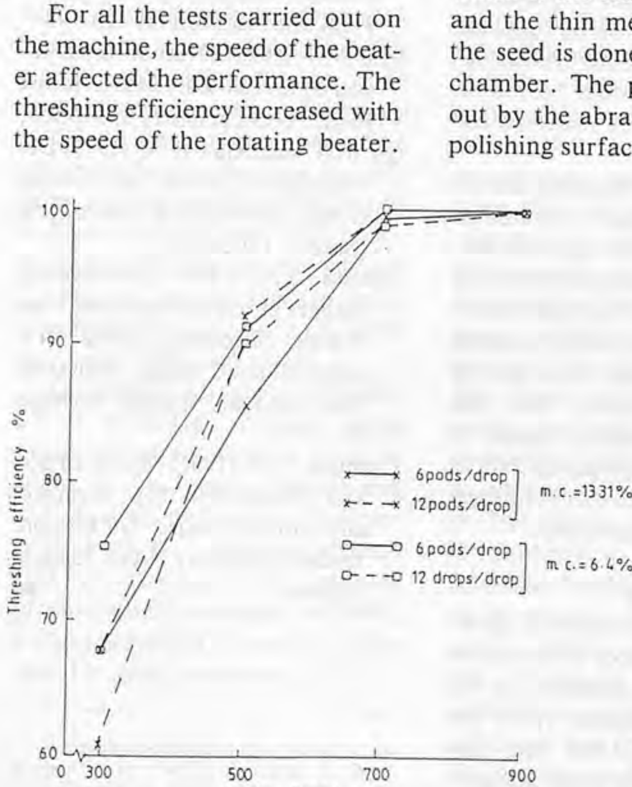


Fig. 2 Threshing efficiency as affected by beater speed.

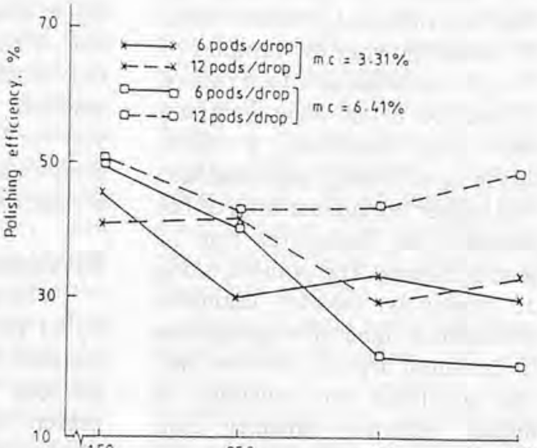


Fig. 3 Polishing efficiency as affected by polisher speed.

difficult for the polisher to remove.

The material capacity of the thresher was influenced by the speed of the threshing beater, the feed rate and the moisture content of the sample. At lower speeds of 300 and 500 rpm of the beater, no significant change could be observed at 5% level, although the sample with 13.31% moisture slightly gave a decrease in capacity as the speed increased to 500 rpm. Beyond this speed an increase in thresher capacity was observed (**Fig. 4**).

Higher feed rate gave a higher capacity at higher speeds. This was not so at the lower speeds as more materials were retained in the machine. The fan could not develop enough pressure to suck the chaffs at low speed and, as a result, a choking condition eventually resulted.

Higher material capacity was recorded for samples at 13.31% moisture than those at 6.41%. The higher moisture level of the samples made the fibrous rim of the pods softer for the knife edges of the spikes to cut and the abrasion of the pulp and the thin membrane covering the seeds was easier. This allowed a faster polishing and a lower residence time in the polisher.

A capacity of over 9 kg per hour was obtained at beater speed of about 900 rpm for samples of 13.31% moisture at a feed rate of 12 pods per drop. When operated under this condition, a 100% threshing efficiency was obtained. The higher the surface area of the polisher, the higher the rate of seed polishing. The polisher being of relatively smaller diameter presented a higher throughput due to the small area of abrasive surface available for polishing. A higher material capacity can, however, be obtained by increasing the diameter of the polisher and hence that of the polishing chamber to take more seeds at a time. Operating the machine at about 900 rpm of the beater will give a better performance and a polisher speed of about one-third that of the beater will be required for a higher polishing efficiency. This speed differential has to be considered in pulley selection for the drive system.

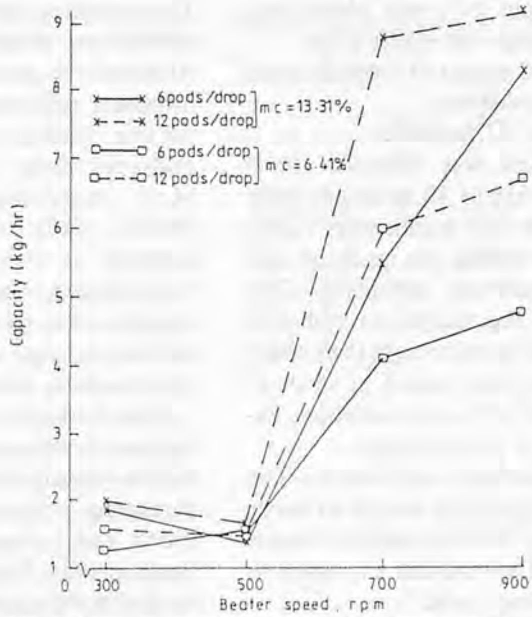


Fig. 4 Thresher capacity as affected by beater speed.

Operating the machine above 900 rpm of the beater resulted in higher seed loss through the fan. The pressure developed by the fan at such speed was too high resulting in more seeds being pumped out of the machine through the fan discharge outlet. For this machine a threshing speed of 900 rpm corresponding to a peripheral (tip) speed of 11 m/s is a reasonable compromise.

Recommendation

To increase the material capacity of the machine, it is recommended that the diameter of the polisher be increased from the present 9.5 cm to not less than 18 cm to facilitate more abrasive surface for the polishing action.

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Performance of Power-operated Groundnut Pod Stripper

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Abstract

This study was conducted using a power-operated double drum groundnut pod stripper with vertical spikes for stripping groundnut. The machine consists of stripping cylinders, blowers and sieve as its major functional components for detaching and cleaning of the pods. The experimental trials were conducted using this stripper for stripping the pods from the uprooted, erect type ICGS 11 groundnut crop. The stripper when operated at its optimum cylinder peripheral speed of 615 m/min (450 rpm) with blower speed 900 rpm (Air velocity of 2.6 m/sec) has an average stripping capacity of 59 kg/h (At 14% m.c. and 40% pod ratio).

Groundnut (*Arachis hypogea. L*) is a major oilseed crop produced in commercial scale in India, China, France, Nigeria and U.S.A. India occupies the first position both with regard to acreage and production. The annual production of groundnut in India is about 6 million tonnes out of the world's total production of 17.3 million tonnes. The growing area is about 7.5 million hectres out of the world's total groundnut growing area of 18.9 million hecters.

The production of groundnut in India has increased for the last 10 years and it is expected to increase further in the coming decade. Therefore, suitable labour saving machineries are required in the harvest and post-harvest operations for this crop. It is observed that early separation of pods gives sufficient time for drying and also helps in fetching a good price in the market. At present the pods are stripped manually by pulling them from the vines immediately after harvest or after spreading the plants under the sun for 24-48 h for drying. Mechanical pod stripping operation greatly helps not only in reducing labour and time but also it minimises the tedious work involved in the stripping operation. Moreover, the output in manual stripping is dependent on the efficiency of the worker, detachability of pods, pod moisture content and the variety of groundnut. As the worker develops fatigue in his fingers during stripping operation by continuous pulling of the groundnut pods from the vines, his capacity to strip gradually decreases.

Important factors affecting the efficiency of the mechanical pod stripping are type of stripping element, speed of operation and condition of the crop. Taking these factors into consideration, a double drum spike-tooth type stripper was developed and its performance studied.

Review of Literature

Antaram et al developed a comb-type stripper using a square frame of four vertical pegs and a horizontal strip of extended metal fixed on each side of the frame of a comb. The stripping of pod is accomplished by drawing a handful of vines across the combs with a slight force. The structure facilitates for four women to work simultaneously. It was reported that the capacity of stripper was 10 kg of pods/h/woman.

Verma and Kalkat also developed a power-operated spike tooth type groundnut thresher operated with 30 hp tractor/15 hp electric motor. The capacity was reported to be 3.75 quintal of pods/h/4 workers.

Naravani and Guruswami developed and evaluated the performance of two-drum type groundnut strippers: one with loop and another with vertical spikes. The optimum speeds were 290 ± 10 rpm and 365 ± 5 rpm for ver-

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tical spike drum and wire loop type drum, respectively. The capacity was reported to be 12.16 kg/h and 26.3 kg/h for vertical spike drum and wire loop type drum, respectively.

Mohanty et al designed a single drum groundnut stripper using vertical spikes as stripping materials and operated by 0.5 hp motor. The capacity was reported to be 24 kg of pods/h/worker.

Materials and Methods

The power-operated pod stripper mainly consists of a rigid frame, two stripping drums, blower unit, a fixed sieve and shaker unit as shown in **Fig. 1.** The two cylindrical closed drums of 33 cm dia. and 45 cm length were made by rolling 1.5 mm thick mild steel sheets and welded properly. Vertical spikes of 6 mm dia. with 50 mm height are welded on the drum in staggered manner. The drums were mounted on a 25 mm dia. shaft, 15 cm apart, with a V-pulley of 25 cm dia. in the middle and properly supported by two bush bearings. Blowers were made from 1.5 mm thick m.s. sheets as blade materials. Two blowers are mounted on the same shaft 15 cm apart with a V-pulley of 12.5 cm dia in the middle and are supported by two bush bearings. The fixed sieve consists of 10 m.s. rods of 6 mm dia. which were welded horizontally at a spacing of 3.5 cm apart on a supporting frame. It retains groundnut plants, branches and roots, if any, that come during stripping operation and allows the groundnut pods, to pass to the shaker sieve. The inclined shaker sieve is made of G.I. sheet which is free to oscillate below the fixed sieve and in front of the blower. The oscillating motion is achieved by means of an eccentric mounted on the stripping drum shaft and suitable links connecting to the shaker sieve. A suitable frame and cover were fabricated. The required power to operate the machine was supplied by 0.5 hp AC electric motor. Provision was also made to get drive from stationary engine or power tiller. The stripper was tested at peripheral speeds of the stripping cylinder of 473 m/min, 540 m/min, 615 m/min and 675 m/min. For each speed of the stripper, the power consumption, threshing efficiency, capacity, breakage percentage, etc. were studied. Observations were also recorded for conventional method

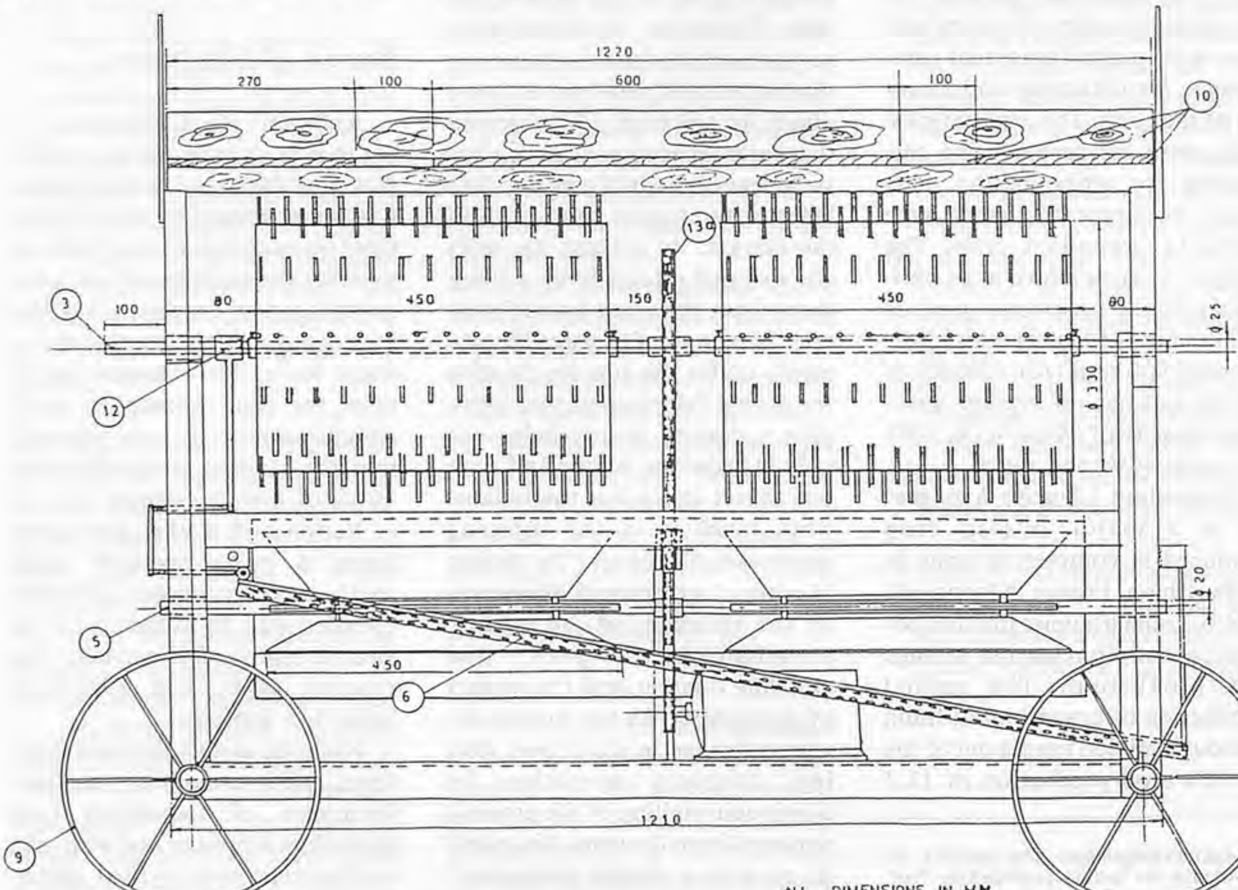

Fig. 1 Power-operated groundnut pod stripper.

of manual stripping followed by the farm workers. The performance of the machine is given in **Table 1.**

Results and Discussion

The performance of the stripper with ICGS 11 groundnut crop was evaluated considering some independent variables like peripheral speeds, moisture content with the dependent variables like capacity, stripping efficiency and breakage percentage which are discussed below:

Effect of peripheral speed on stripping capacity—The stripping capacity of the stripper varied from 31.3 kg/h to 72 kg/h while peripheral speed varies from 473 m/min to 675 m/min **(Fig. 2)**. The low stripping capacity of 31.8 kg/h at a peripheral speed of 473 m/min, is due to comparatively low energy of impact for detaching the pods and holding the bunch of vines for a longer period for proper detachment of pods. It is observed that the capacity of stripper increases with an increase in peripheral speed. The increase in capacity was at an increasing rate from peripheral speed of 473 m/min to 615 m/min and then decreased rapidly to the cylinder speed of 675 m/min. At a peripheral speed greater than 615 m/min, the spikes did not penetrate into the bunch of vines and, hence the combining action by the spikes was not effective. Also, it is difficult to hold the bunch at high speed.

Effect of peripheral speed on stripping efficiency—The stripping efficiency of the stripper varied from 94.66% to 97.25% at a pod m.c. of 24.49% (wb) which is reasonably high **(Fig. 3)**. The maximum stripping efficiency of 97.25% was achieved at the lowest peripheral speed of 473 m/min which was primarily due to proper

Table 1 Effect of Cylinder Peripheral Speed on the Performance of Stripper (for groundnut variety of ICGS 11 at 24.49% m.c. (w.b.) and 42.85% Pod Ratio)

Peripheral speed (m/min)	Capacity (kg/h)	Corrected capacity (kg/h)	Stripping efficiency (%)	Unstripped pod (%)	Shelled pod (%)
473	31.8	26.064	97.25	2.75	0.10
540	52.8	43.276	97.24	2.76	0.75
615	72.0	59.012	96.78	3.22	0.75
675	37.2	30.490	94.66	3.54	3.00

N.B. 1) Corrected capacity has been calculated at 40% pod ratio and 14% pod moisture (wb) by using the relation.

$$W_1 = \frac{W\,(M-14)}{86} \times \frac{40}{R}$$

where, W_1 = Corrected capacity
W = Output-capacity
M = Observed moisture content
R = Observed pod ratio (%)

2) Capacity of manual stripping was 4.5 kg/h per labour at 14% m.c. (w.b.)

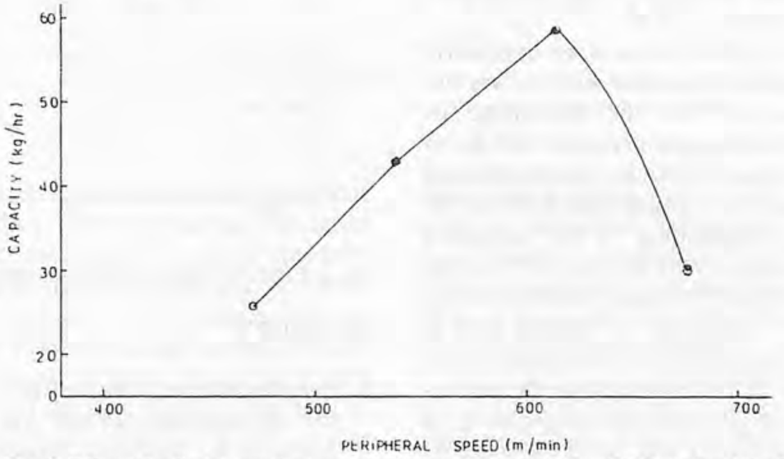

Fig. 2 Effect of cylinder speed on corrected capacity (14%MC and 40% pod ratio) of stripper.

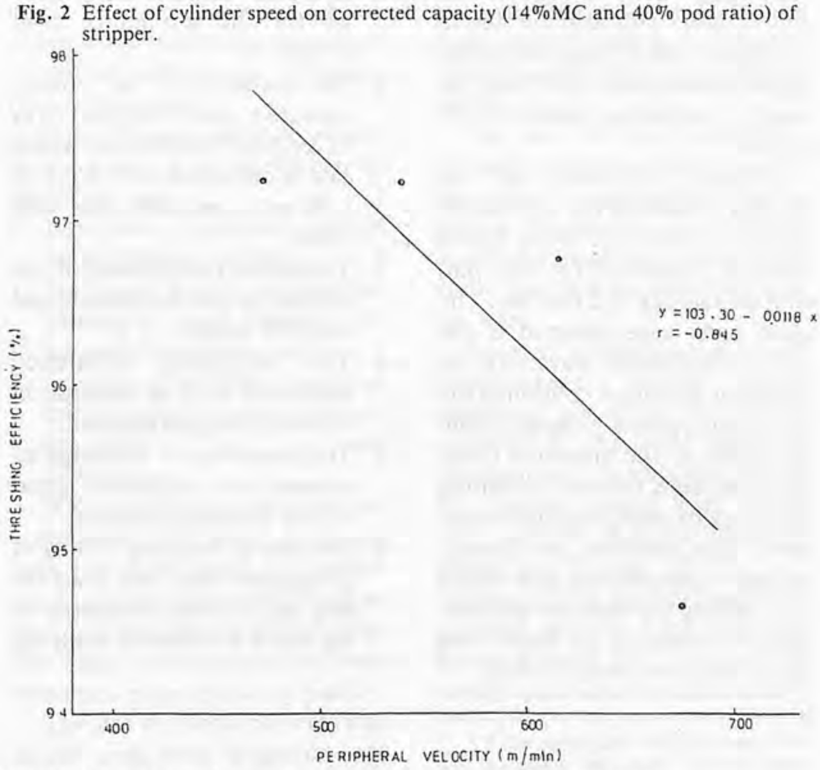

Fig. 3 Effect of cylinder speed on threshing efficiency of groundnut.

combined action of spikes while the minimum stripping efficiency of 94.66% was achieved at a speed of 675 m/min which may be due to improper penetration of spikes inside the bunch of vines at higher speeds. This shows that speeds beyond 615 m/min is not suitable for the pod stripper for the ICGS 11 crop. Considering the above facts the peripheral speed of 615 m/min is taken to be optimum for which the stripping efficiency is 96.78% and capacity is 72 kg/h at 24.49% pod m.c. (w.b)

Effect of cylinder peripheral speed on shelled pod—It was observed that the percentage of shelled pods increased with an increase of cylinder peripheral speed and that ranged from 0.1% to 3% corresponding to the peripheral speed of 473 m/min to 675 m/min (Fig. 4). It is seen that the increase in percentage of shelled pods is marginal up to the cylinder speed of 615 m/min and then the percentage of shelled pod increased at an increasing rate up to the speed of 675 m/min. This may be due to the greater energy imparted by the spikes causing rupture of pods beyond a peripheral speed of 615 m/min.

Cleaning efficiency of the stripper—Initially the dry leaves, dust, etc. were effectively blown away by the blower (at 900 rpm) with air velocity of 2.6 m/sec. The clean pods were collected at the end of the shaker sieve. As the stripping operation continued the groundnut plants slipping from the hands of the operators cover the fixed sieve, thereby preventing easy flow of pods onto the shaker sieve. This problem, particularly at higher cylinder rpm, was solved by stopping the machine periodically for cleaning the fixed sieve which required about 2 min.

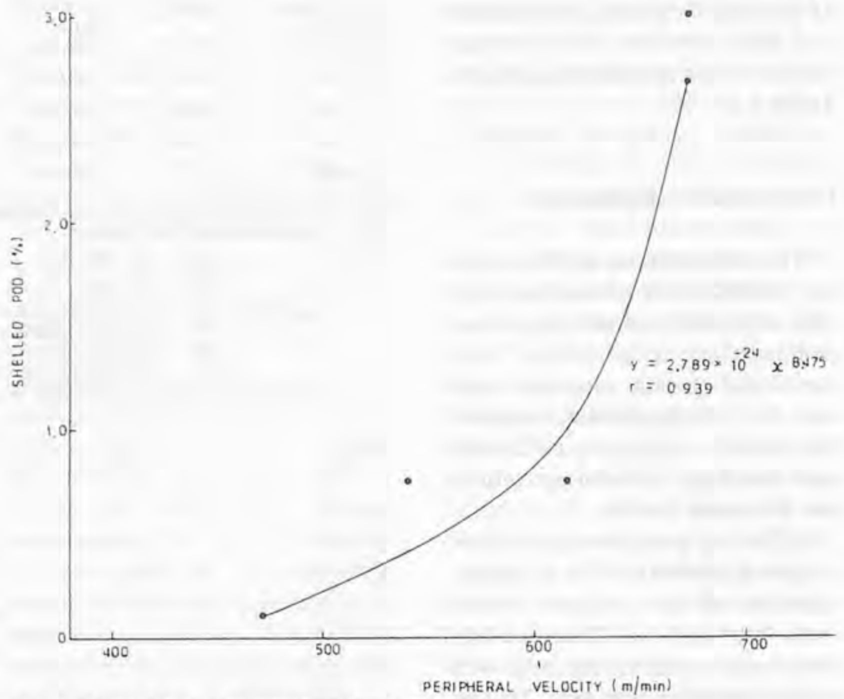

Fig. 4 Effect of cylinder speed on breakage of groundnut pods.

Conclusion

1. Peripheral speed of 615 m/min for the stripping cylinder was optimum for maximum capacity for the groundnut crop ICGS-11.
2. The capacity of the power-operated pod stripper was 72 kg/h at 24.49% m.c. which can be corrected to 59 kg/h at 14% m.c. and 40% pod vine ratio.
3. The power requirement of the stripper at the optimum speed was 350 watts.
4. The stripping efficiency decreased with an increase in cylinder peripheral speed.
5. The percentage of breakage increased with peripheral speed of the stripping cylinder.
6. The cost of stripping 100 kg of groundnut with this machine was Rs.11.00 as compared to Rs.30.00 by manual stripping

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An Experimental Apparatus for Simultaneous Spreading of Plastic Mulch and Drip Irrigation Pipes

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Abstract

A prototype plastic mulch, drip irrigation pipe layer was developed and tested. The layer simultaneously cut the soil, formed it into an 800 mm square bed, laid an agro-drip irrigation pipe in the middle of the bed, and covered it firmly with a plastic mulch. The machine was ground driven and carried by a 45 kW tractor's three point linkage.

Introduction

Arid and semi-arid climates are generally characterized by high solar radiation, low humidity of the air, and high evaporation of water from soils and plants. They are defined as one in which, for the greater part of the year, precipitation is less than the potential evapotranspiration; that is evaporation plus water loss from plants (Arnon, 1972). The amount of precipitation is low, non-uniformly distributed throughout the production seasons, and varies unpredictably in both intensity and quantity from year to year.

Much of the arable land of Lebanon belongs to this climatic region. Of those areas, the Beqa'a and Al-Qua'a plains make up a definable region in which a great majority of farmers grow watermelon, cantaloupe and snake cucumber without any irrigation (fallow farming).

Such a practice generally results in a low crop yield which can be attributed to:

1. Low plant population density under fallow farming;
2. Soil water loss by evaporation causing a quick depletion of naturally available water;
3. Scarcity of available water at critical growth stages, specially during fruit set and development.

Water scarcity coupled with the urgency of more water for irrigation, have convinced the farmers to adapt to management practices that optimize the use of their land and water resources and maintain optimum economic crop yield.

The use of black polyethylene mulch and drip irrigation are among the several known management approaches in crop production in semi-arid conditions. Supplemental irrigation, even when limited, can be of great assistance to a crop when provided at its critical growth stages.

Mulching has long been known as a means of reducing evaporation losses. These losses contribute from one-fourth to one-half of the evapotranspiration loss of a crop (Fritschen and Shaw, 1961; Peters 1960).

The use of this technology, however, requires adaptative cultivars and a practically feasible system of laying the polyethylene-mulch and the drip irrigation pipes in the field in a fast and labor saving way.

Several commercial and experimental mulch laying machines are either known or available in the local market:* (Mechanical transplanter model 90, Holland mulch layer model 1275, MF 357, Kennco PS series, Huges and Tiessen, 1971).

None of the known machines, however, perform both polyethylene mulch and drip irrigation pipe laying operations simultaneously.

Note: Based on research conducted at the Agriculture Research and Education Center — Faculty of Agricultural and Food Sciences — American University of Beirut. Beirut, Lebanon. Funded by a grant from the University Research Board.

* Tade names are used for identification purposes only and do not imply endorsement.

Traditionally, the two operations are carried separately using two different machines. This implies higher energy and labor expenses and a larger capital investment cost in operationally specific machinery. Moreover, a more severe damage is expected to the field due to tractor-implement trafficability.

Numerous factors other than the above mentioned demand that a polyethylene mulch; drip irrigation pipe layer be developed. Those factors include:

1. The regional production and availability of the Agro/Drip[R] — drip irrigation pipe system. The drippers of this system are integrated in the pipe wall which eliminates the need for connecting the lateral pipe drippers and allow for practically laying the pipe under the mulch,
2. The local cultural practices of planting on an 800 m wide, 150-200 m raised beds with the drip irrigaiton pipe positioned in the middle of the bed and under the polyethylene mulch;
3. The local manufacture of the machine which makes its price reasonable and attainable to the farmers and provide a stock of readily available spare parts.

Objectives

The objectives of this research were:

To design and construct a prototype polyethylene mulch, drip irrigation layer with the following physical and functional criteria:

a. Establish an 800 mm wide, 150-200 mm high bed;
b. Layout the drip irrigaiton pipe in the middle of the bed and at a depth of 50-70 mm;
c. Firmly cover the bed (including the drip irrigation pipe) with a layer of black polyethylene mulch;
d. Automatically unroll the drip irrigation pipe and plastic mulch whenever the machine is soil engaged;
e. The machine should be ground driven and mounted on the 3-point tractor linkage system.

To test the prototype for component performance, stress tolerance, achievement of functional objectives, field capacity and efficiency and economic feasibility.

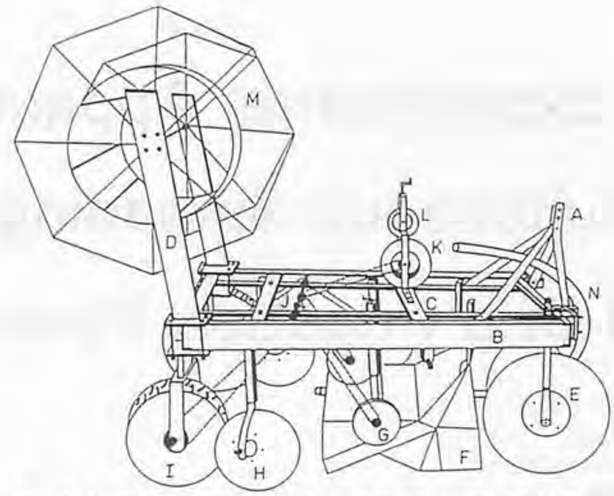

Fig. 1 A schematic representation of the designed machine.

Machine Development and Components Testing

The machine design parameters and a prototype blue print plans were developed in the Spring 1985. This included a general layout and drawing of the machine, its theoretical mechanisms synthesis, components operational and assembly sequence and timing, and system stress analysis. A prototype machine was developed and preliminarily tested during the Summer and early Fall, 1985.

The machine consisted of four major subsystems **(Fig. 1)**:

Implement Chassis and Transport Subsystem

This subsystem included the 3-point hitch linkage (A), the machine chassis, plastic-mulch carrier (C), and the drip irrigation pipe carrier system. The linkage system is made of 55 mm wide, 17 mm thick flat steel bars designed to accommodate a category II three-point tractor linkage system. The two front bars of the linkage were connected to the 1260 mm long front I-beam (140 mm × 65 mm × 11 mm) of the machine chassis. Another similar beam was located at the rear of the chassis. The rear bars of the linkage were bolted to the inner chassis beams (40 mm × 65 mm × 9 mm I-beam). The two side beams of the chassis (B) were each a 2.05 m C-shape (120 mm × 55 mm × 10 mm).

On those beams, a steel beam (C) was bolted and served as a carrier of the drip irrigation pipe feed mechanism (K) and the plastic mulch carrier rod (22 mm diameter steel rod). The rod could be slipped out of the beam arms through two journal bearings to allow for mounting the plastic mulch roll.

The drip irrigation pipe was fitted to the 1.2 m wide unrolling barrel (M). The barrel consisted of a 22 mm central axis steel rod welded on both sides to eight 6 mm rods that formed the barrel side brackets. At a radial distance of 335 mm from the central axis rod, two 100 mm wide by 8 mm thick flat steel bars were shaped into a circle and welded to those rods, one on each side. Those circles acted as a support bracket for eight (20 mm id) steel pipes fitted parallel to the central axis and serving as the skeleton on which a 1 mm thick sheet metal was riveted.

The barrel side brackets were extended 220 mm — a distance enough for mounting a 1000 m long drip irrigation pipe on the barrel. The barrel's diameter (670 mm) was the minimum required for rolling the drip irrigation pipe without affecting the inner pipe spiral feed channel and consequently plugging the water flow to the drippers.

The drip irrigation pipe unrolling barrel system was carried by its central axis on two journal bearings fitted on two 890 mm long rectangular steel columns (100 mm × 40 mm × 4 mm). The columns were each mounted by steel brackets (170 mm × 100 mm × 15 mm) on the corner of the chassis side and rear beams using four 20 mm diameter bolts.

Bed Formation Subsystem

This subsystem consisted of the disc bedders (E), the bed shaper (F) and the mulch burying discs (H). The disc bedders (E) are each a 660-mm diameter discs mounted by a 40 mm diameter high carbon steel rods bolted to the front chassis beam by 25 mm bolts and two medium carbon steel brackets (200 m × 100 mm × 30 mm). The front and rear distances between the discs were 1.04 m and 540 mm, respectively, with a disc and tilt angle of 41° and 21°, respectively. The cutting depth was set at 220 mm — a depth just enough to provide the needed earth for the bed formation.

The bed shaper (F) was mounted 40 mm behind the rear central tips of the bedder discs. It was mounted to the inner chassis beams by two (40 mm × 40 mm × 3 mm) square steel columns welded to the top of the bed shaper and bolted by 18 mm C-shape bolts to the beams. The bottom of the bed shaper was 120 mm higher than that of the disc bedders.

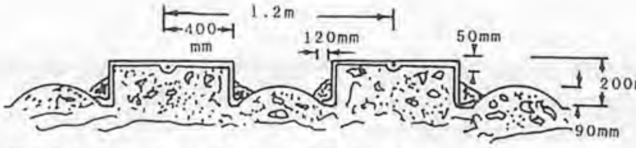

Fig. 2 A cross-sectional view of a laid-out bed.

This height made it possible for both forming the raised bed and providing a furrow for burying the sides of the mulch. A detailed description of the bed shaper dimensions is shown (**Fig. 2**). Two 480 mm diameter mulch-burying discs (H) were oppositely placed at a distance of 80 mm behind the back and 85 mm off the side of the bed shaper at a disc and tilt angle of 45° and 19°, respectively. Each was mounted to the inner-chassis beam by a (40 mm × 65 mm × 9 mm) C-shape high carbon steel beam welded to a 38-mm disc rod and bolted to the inner beam by an 18-mm diameter C-shape bolts. The mulch-burying discs were set at a depth of 65 mm below the bottom of the bed shaper, a depth enough for providing the needed earth for burying the ground laid mulch while maintaining a sufficient height above it.

Material Layout and Handling Subsystem

This subsystem included the plastic mulch feed system (G), and the drip irrigation pipe drive system (K, L) and its guide (N).

The plastic mulch system (G) consisted of three 250 mm diameter, 55 mm wide rubber wheels. The outer two were each mounted by their bearings on a (35 mm × 35 mm × 3 mm) square steel column fitted inside another (40 mm × 40 mm × 4 mm) square steel column. the first column could be slid upwards and downwards inside the second (bolted to the inner-chassis beams) using a jack type arrangement. This permitted the operator to raise the unrolling wheels when fitting the plastic mulch under it at the beginning of the operation. Those wheels assisted in unrolling the plastic mulch, but more importantly, shaped the mulch along the corners of the bed shaper and allowed it to be side buried by the mulch-burying discs. The centers of the wheels were 60 mm in front the central axis of the flattening surface of the bed shaper. This was the best location (after trying several other positions) which secured the mulch unrolling but at the same time saved it from being torn during feeding.

The central wheel was mounted by a similar arrangement, except that in this condition positioning was bidirectional (upwards and downwards and forward and backward). This provided an infinite directional combinations for selecting the most optimal unrolling operation.

The drip irrigation pipe feeding unit consisted of a rubber wheel similar to that of the plastic mulch unrolling system. The wheel counter rotated against another 140-mm idler rubber wheel. The clearance between both wheels could be varied by either lifting or lowering the idler wheel using its jack type arrangement. This permitted different diameter drip irrigation pipes to be installed, initial pipe feeding, and pressure increase on the pipe to minimize slippage and secure appropriate pipe feeding. The pipe orienting guide (N) was made up of a 50 mm internal diameter steel pipe welded to the rear bars of the 3 point linkage system and to the inner surface of the bed shaper flat square unit. The beginning of the guide was 80 mm ahead of the drip irrigation pipe feeding wheels (K).

The curvature of the guide was 670 mm diameter to minimize the friction resistance to pipe feeding. Both the plastic mulch roll and the drip irrigation pipe unrolling barrel rotated under the pull of material by the feeding system.

Machine Components Driving Subsystem

This subsystem consisted of the ground-driven drive wheels (I), the central drive unit (J), and the drive mechanisms of the plastic mulch-drip irrigation pipe feeding systems.

The two ground-driven drive wheels (I) were each a 430-mm diameter rubber wheel mounted to the rear beam of the machine chassis. The wheels were positioned so that their inner surfaces coincided along the sides of the bed shaper. The wheels' bottoms were 50 mm higher than that of the bed shaper. Each wheel rotated a 26-teeth (5/8 pitch single strand) sprocket connected by a chain to two 14-tooth sprockets fitted to the central drive unit (J). This unit was made of a 22 mm medium carbon steel rod mounted by two journal bearings on the chassis inner beams. The drive had four more 14-tooth sprockets of which three were each connected to a 14-tooth sprocket mounted on the plastic mulch feeding wheels. The fourth sprocket was connected to a 15-tooth sprocket fitted to the drip-irrigation pipe feeding system. Such a power transmission combination gave a ground distance to a material unrolling approximate ratio of 1:1.1 for the plastic mulch and 1:1 for the drip irrigation pipe. It was thought that the length of the plastic mulch should approximately be 8-10% more than that of the covered ground surface to compensate for the changes in its surface area due to thermal expansions and contractions.

Machine Mode of Operation and Performance

The different mechanisms of the machine were activated by the ground-driven rotation of the press wheels (I) upon lowering and engaging the machine in the soil. The disc bedders opened a ditch 1.04 m wide and approximately 200 mm deep. This provided a ridge approximately 600 mm wide and 450 mm height at its center. The cut earth was then admitted into the bed shaper, whose design permitted to gradually allow the ridge to be flattened and refashioned into a square bed. The drip irrigation pipe guide (N) opened a 50-mm deep furrow in the middle of the flattened bed. It was fed through the guide by the rotation of the pipe feeding mechanism (K, L). This mechanism, driven by the central drive unit (I), pulled the pipe from the barrel (thus allowing the barrel to rotate in proportion to the ground) and oriented it into the guide. Simultaneously, the central drive unit rotated the three plastic-mulch feeding wheels. This rotation pulled the mulch from its carrier and unrolled it over the bed where it was laid above both the bed and the drip irrigation pipe. The plastic mulch was oriented at the end of the bed shaper side slides into the bed furrow and next to the mulch burying discs. Those discs then covered the mulch on both sides of the bed. The drive wheels finally, firmly pressed the soil that covered the plastic-mulch.

The bed dimensions and layout and the inter-bed distances are shown **(Fig. 3)**. The optimal speed at which the machine was operated was 4 km/h. This resulted in a theoretical capacity of 0.48 ha/h. However, the average observed field capacity was 0.31 ha/h, rendering the machine field efficiency at 65%. At higher operational speeds, the soil passed over the front edge of the bed shaper and was jammed between the plastic mulch and the surface of the square unit of the shaper. This resulted in mulch tear and in the reduction of the pulling ability of the plastic-mulch unrolling wheels.

The initial diameter of the plastic mulch burying discs were 360 mm. This did not, however, cut and mobilize enough soil to firm-

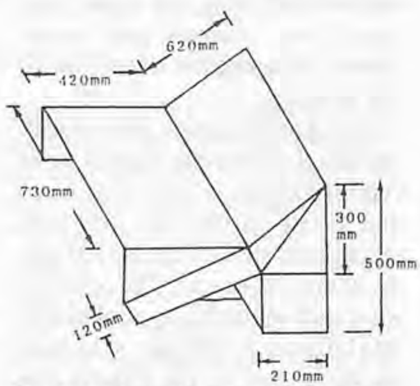

Fig. 3 A schematic representation of the bed shaper.

Fig. 4 A general view of the machine.

Fig. 5 A view of the machine and the laid mulch.

ly bury the mulch. The new discs (as currently fitted) were mounted 50 mm deeper than what the previous discs were set at.

The ground-driven drive wheels were originally 320 mm diameter, flat, rubber, air filled press wheels with 16 teeth (5/8" pitch single strand) sprockets. There was not enough torque generated through those wheels to drive the mechanisms of the machine. In addition, the soil burying the mulch were not firmly pressed over the mulch.

The drip irrigation pipe guide (N) was initially designed in a form that followed the contour of the middle of the bed shaper inner surface. This created a wedge at the point in the guide where the contour following the front end part joined the flat surface. In addition, the curvature diameter was 400 mm and was neither enough for a minimal friction pipe feeding nor appropriate for protecting the pipe against the sharp wedging that affected its internal channel structure.

Performance was better with slightly moist soils since the formed bed maintained its square shape and, consequently, the plastic mulch was better fitted over it.

The maximum capacity of the drip irrigation pipe carrier was 1000 m of a 25 mm diameter pipe. The capacity of the plastic mulch carrier was approximately 800 m. The total mass of the machine was 772 kg while the average draft was 11.2 kW.

Machine Economic Feasibility

The average annual cost of using the three known laying systems of both the drip irrigation pipes and plastic mulch on a hectare basis were compared (**Table 1**). This cost was first calculated based on rates pertaining to local currency and then converted to dollars. The straight line depreciation, fixed-variable method was used (Hunt, 1976). In this method, the hourly use was set at a time period that a hectare required to be laid with the pipe and the plastic mulch. Machine salvage value was set at 10% of the actual original cost and the machine average life was 12 years. A 10% interest rate was used in the calculations while a 1% of the initial cost was approximated for the cost of taxes, insurance and shelter. Values of 0.048 and 0.25 were adopted for the repair and fuel and lubricant cost factors, respectively. Labor rate was set at $0.5/h. The compared systems were: the manual, conventional and prototype layer.

The manual system was comprised of mechanically establishing the beds (a custom-rent operation) and then manually laying the drip irrigation pipes and the plastic mulch over it. The average tested input to this operation was 30 man-h per 1000 m^2 (SD = 4.19) or 300 man-ha. The approximate cost/ha for local custom renting a bedder is 10 dollars.

The conventional system consisted of mechanically laying the drip irrigation pipe (using a bedder-pipe layer) and then covering it with plastic mulch (using a mulch layer). The initial cost of a pipe layer and a mulcher was 1,200 and 3,000 dollars, respectively. The estimated average labor requirement was 12 man-ha for both operations.

The third system was comprised of using the newly developed prototype layer. The initial cost was set at 1,500 dollars — a lower rate with respect to the conventional system machines since this layer was locally manufactured. The estimated average labor requirement was 3 man/ha.

The prototype layer showed definite savings against the conventional system. In addition, whenever the total land area to be covered was more than 1.42 ha/year, the use of the prototype layer became even cheaper than manually laying the pipes and the mulch.

Table 1 Comparison of Average Annual Costs ($/ha) of Laying a Drip Irrigation Pipe and a Plastic Mulch Among the 3 Known Laying System.

Cost item/Laying system	Manual	Conventional	Prototype layer
Depreciation	—	315	113
Interest	—	231	83
Tax, insurance, shelter	—	42	7
Repairs and maintenance	—	10	6
Fuel and lubricants	—	8	6
Labor	150	6	2
Other	10 (cost of bed establishment)	—	—
Total	160	612	226

Recommendations

The prototype layer was a feasible machine that showed a significant promise in developing the use of the plastic mulch, drip irrigation technology in semi-arid regions. However, further research should be carried out to improve on the performance of the machine, specifically;

1. Develop an automatic irrigaiton-pipe, plastic mulch termination system;
2. Substitute the fixed dimension bed shaper with a variable one, especially in terms of its width;
3. Develop a multi-unit drip-irrigation pipe feeding and orienting system; and
4. Improve on the machine-field capacity.

(Continued on page 38)

Effects of Four Soil Tillage Methods on Growth of Maize in Zambia

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Abstract

The effect on the growth of maize of four soil tillage methods suitable for animal traction was studied. The effect of ploughing, ripping, ridging and no-tillage were compared in two successive growing seasons. No-tillage gave far worse results than any of the other three treatments. The best results were obtained by ploughing and by ripping.

Introduction

Many developing countries strive for an increase of their agricultural production in order to feed the rapidly growing population. Contrary to many other countries, Zambia still has the possibility to expand the cultivated area since there is no lack of suitable land yet.

Approximately 80% of the gross output of agriculture comes from 400 large-scale commercial farms using modern technology and power equipment (Kouwenhoven, 1983). In contrast with them, the large majority of Zambian farmers cultivate only a small piece of land using the hoe. To increase the farm size (and thus the cultivated area) and to improve the quality of tillage of this last group of farmers the use of animal traction is promoted more and more. It offers new possibilities: less time is needed for tillage, making earlier planting possible, the deeper tillage may result in better weed control and more favourable soil conditions. But the animals will need feeds, which take up land for grazing. They must be taken care of and be trained for their task. Another problem is the fact that the heaviest work (the main tillage operation of the soil) has to be done just after the dry season when the animals are not in optimal condition. The use of oxen (most common draught animals in Zambia) automatically includes the introduction of appropriate tillage methods.

Zambia is located in a semi-arid region with a distinct rainy season from October through April. The rain that falls during this period must be used to ensure acceptable crop yields. Rainfall in Zambia is often intensive because of concentration in short periods. This may cause the destruction of soil aggregates and compaction of the soil surface, resulting in a low infiltration rate and run-off of ponding water. For soil tillage this means that it is important to create strong and stable aggregates to resist the impact of rain drops, to improve the infiltration and to improve the water holding capacity. Apart from improving the soil structure, the weed growth must be controlled, a good seedbed must be prepared, crusts must be broken and sometimes residues of the previous crop must be buried.

Not much is known yet about the best way to till the soil under Zambian conditions. Therefore, it is important to study the performance of different tillage methods under Zambian climatological conditions and on a soil type typical for Zambia. The Department of Agricultural Engineering of the University of Zambia in Lusaka decided in 1986 to set up a soil tillage experiment based on a previous research project of the university (Gill, E.A., 1985). The aim was to investigate the effects of the main tillage operation on the crop growth. Because maize is

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The advice given by Dr. ir. J.K. Kouwenhoven (Tillage Laboratory of the Wageningen Agricultural University) is highly appreciated.

Table 1 Particle Size Analysis of the Soil

Depth (cm)	% clay (< 2 μm)	% silt (2-50 μm)	% sand (> 50 μm)	Classification
0- 24	21.7	17.6	60.7	sandy clay loam
24- 38	28.5	16.8	54.7	sandy clay loam
38- 66	34.9	15.3	49.8	sandy clay loam
66-109	41.9	13.8	44.3	clay
109-157	44.5	13.9	41.6	clay
157-195	42.0	15.9	42.1	clay

Table 2 Weather Conditions During the Experiment

Item	Jan.-April 1987	Jan.-April 1988	Long term average
Rainfall (mm)	349	553	541
Days > 1 mm rain	22	36	45
Aver. TMAX (°C)	28.7	27.3	26.0
Hours of sun/day	8.6	6.9	6.3

the staple food in Zambia and is grown by almost all small farmers, it was chosen to be the test crop. The soil on which the experiment was carried out is quite common in Zambia and in other parts of Southern Africa. Management practices like weeding and application of fertilizer were according to the local recommendations.

Materials and Methods

Soil Type

The experiment was carried out at the university farm. It is located some 20 km east of Lusaka (15° S, 28° ES), at an elevation of 1150 m. The soil has been classified as an Eutric Nitosol (FAO-classification) and in Soil Taxonomy as an Oxic Paleustalf (Chinene, 1980). Its texture ranges from sandy clay loam in the upper layer to clay in the subsoil, as can be seen in **Table 1**.

According to Lenvain et al (1987) the soil is characterized by a structure which is sensitive for reconsolidation. This manifests itself in a low infiltration rate, a very low hydraulic conductivity and a field capacity of only 108 mm/m (Lenvain and Pauwelijn, 1986). Dry bulk density of the soil (measured just before the rains) was 1430 kg/m^3. Chemical fertilizer is low: it ranges from 6 to 8 meq/100 g. The organic matter content of the upper layer is 1.97% and the pH is 5.3. The properties of the soil may result in reduced root proliferation and make the soil prone to drought.

Weather

The 1986-1987 rainy season was characterized by too little rain and several longer periods without any rainfall at all, whereas the 1987-1988 rainy season was much wetter, as can be seen from **Table 2**.

Experimental Design

The experiment was carried out during the 1986-87 and 1987-88 growing seasons. It was a randomized complete block design with four tillage treatments and four replications. The size of each plot was 10 × 5 m.

The row spacing was 75 cm and the plant spacing in the row was 25 cm, corresponding with a density of 53 000 plants per ha. Each plot thus had 7 plant rows of 10 m long. Maize variety MM 752 was used. Two seeds per seeding-hole were planted by hand at a depth of 5 cm (10 cm on the ripped fields). A few weeks after emergence the smallest of the two plants was cut off.

At the time of planting a basal dressing of D-compound (10% N, 20% P_2O_5, 10% K_2O and 10% S) was applied along the planting rows at the rate of 300 kg/ha. Six weeks after planting a top dressing of 200 kg/ha urea was applied (46% N).

Emergence was calculated by expressing the actual number of plants as a percentage of the number of seeds put into the ground. The height of the plants was estimated by measuring the length of every tenth plant.

To avoid side effects, the two outer rows, as well as 1 m at the short ends of the plots were not harvested, as shown in **Fig. 1** making the harvested area 30 m^2.

Tillage Methods

Ploughing and Harrowing — The first soil tillage method considered in this experiment was ploughing followed by harrowing. It is very common in all kinds of cropping system all over the world. Ploughing loosens and inverts the soil, and harrowing crumbles the remaining clods.

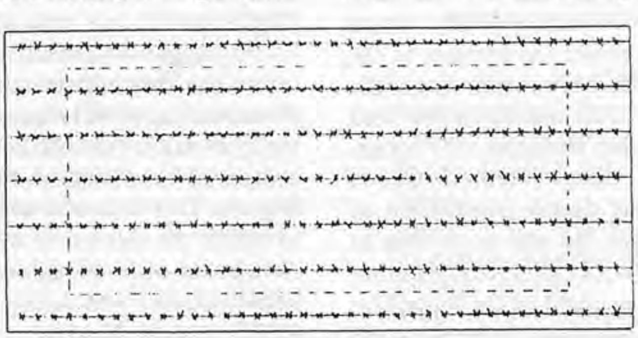

Fig. 1 Layout and harvested area of a plot.

Fig. 2 Effect of ploughing and harrowing.

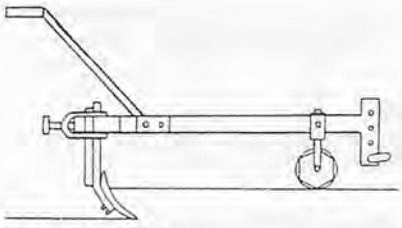

Fig. 3 The ripper.

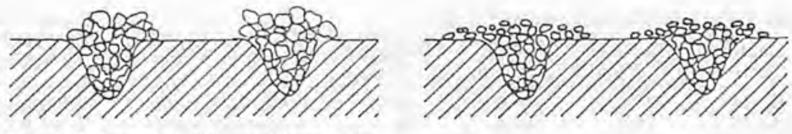

Fig. 4 Effect of ripping and harrowing.

Fig. 5 Effect of ridging.

Fig. 6 No-tillage.

Though soil inversion disturbs the natural profile, the weed controlling effect is considered to be more important. Whether this is a valid reason for a tillage operation which inverts the soil in the (semi-) arid tropics is doubted by many authors.

Ploughing was done with a single-furrow, non-reversible mouldboard plough, suitable for animal traction. The depth of ploughing was 12 cm and the width 20 cm. Afterwards the field was harrowed, using a multi-purpose tool-carrier fitted with a beam with springtines (working width of 120 cm).

Ripping and harrowing — A less common method is the use of a ripper-tine for the main tillage operation. A tine is pulled through the soil to break it up. This is only done in the planting rows, leaving the rest of the soil undisturbed.

According to Buckingham (19884) the best results are obtained on a dry and firm soil. Lungu and Matakala (1988) found that the power requirement of the ripper-tine is lower than that of the plough. This allows earlier land preparation when the soil is drier.

This tillage method allows faster and deeper penetration of roots into the soil according to Chaudhary et al (1985). Another advantage might be the concentration of rainwater from the compact soil between the rows in the loosened planting rows.

To prevent germination after only a light shower, the seeds are placed a bit deeper than usual.

The same tool-carrier was fitted with a chisel-tine **(Fig. 3)** and was used at a depth of 25 cm. Only the loosened strips were harrowed.

Ridging — Growing maize on ridges is a very common practice among the small farmers in Zambia. The ridges are formed and maintained with a hoe or, if oxen are available, with a ridger. According to Webster and Wilson (1980), possible advantages of ridges are controlling of weeds by burying, placing well manured surface soil near the roots and better drainage during heavy rainfall. They report positive effects found in experiments in Kenya, Tanzania and Zambia and variable results found in Tanzania and Uganda. The frequent occurence of this system in Zambia made it useful to include it in the experiment.

A ridger (double mouldboard plough) attached to the tool-carrier made ridges of about 20 cm high and at distances of 75 cm **(Fig. 5)**.

No-tillage — Direct drilling leaves the existing structure undisturbed. Lal (1985) reports a better infiltration rate for no-tillage compared to ploughed fields in Nigeria. This is caused, according to Lal, by the collapse of transmission pores after ploughing. The same tendency was found by Ike (1986), also in Nigeria.

On the other hand, Webster and Wilson (1980) report a deterioration of water infiltration and storage in no-tillage systems. Charreau (1978) states that all soils having a clay content less than 20% need deep (> 15 cm) tillage to create a favourable structure. The soil in this experiment has a clay content of 21.7% in the upper layer, which is close to Charreau's limit.

To assess the value of no-tillage for Zambian agriculture it was one of the investigated methods.

The only operation on the no-tillage plots was the removal of all weeds, using a hoe.

Results

During both growing seasons the emergence, height of the plants, grain yields and weed growth were recorded. The results are presented in **Tables 3** and **4**.

Only the differences in height of the maize plants proved to be significant in both seasons: ploughing and ripping resulted in the tallest plants, no-tillage in the shortest. During the second season the emergence on the ripped plots was significantly higher than on all the other plots. The weed population in the no-tillage plots three weeks after planting in the second season was significantly larger than on the ploughed and ridged plots.

Due to the hot and dry weather during the first season grain yields were extremely low and the difference were not significant. The bad performance of the no-tillage plots during the second season is very pronounced.

Table 3 Crop and Weed Growth During the 1986-1987 Growing Season (wap = weeks after planting)

Method	Emergence (%) 5 wap	Height of plants (cm) 6 wap	15 wap	Grain yield air dry (t/ha)	Weeds d.m. (g/m^2) 4 wap	7 wap
Ploughing	59	67	123	0.28	28	102
Ripping	70	70	122	0.45	80	44
Ridging	58	49	104	0.23	78	50
No-tillage	44	37	86	0.16	64	80
LSD (p = 0.05)	NS	9	20	NS	NS	NS

Table 4 Crop and Weed Growth During the 1987-1988 Growing Season (wap = weeks after planting)

Method	Emergence (%) 6 wap	Height of plants (cm) 6 wap	Grain yield air dry (t/ha)	Weeds d.m. (g/m^2) 3 wap
Ploughing	72	110	6.97	126
Ripping	92	112	6.07	242
Ridging	68	97	6.30	140
No-tillage	56	63	3.30	518
LSD (p = 0.05)	20	11	1.50	290

Discussion

Emergence seemed low on no-tillage plots and high on the ripped plots. The results of the first season showed such a large spreading, that the observed differences could not be called significant, contrary to the second season: emergence on the ripped plots was significantly higher than on all other plots.

The development of the maize plants showed the same tendency in both seasons: ripping and ploughing resulted in the highest plants. Plants growing on ridges were significantly lower, while the plants on the no-tillage plots clearly showed the slowest growth.

The grain yields of the first growing season were not significantly different, due to the large spreading of the results. The weather conditions during the second season were considerably better, resulting in much higher yields. The yield of the no-tillage plots was significantly lower than the other plots. Although the emergence on the ripped fields was higher than on the ploughed fields, the grain yields were slightly lower. It was observed during harvest that 20% of the plants on the ripped plots did not have a cob, while on the ploughed plots (and the other plots for that matter) this was only approximatelly 10% (the recommended plant density of 53 000 per ha probably is too high for these well managed fields; 40 000 would be enough).

In absolute terms there were considerable differences in the quantity of weeds in both seasons, but these were only significant in the second season: the quantity of weeds shortly after planting on the no-tillage plots was significantly higher than on the ploughed and ridged plots.

No-tillage clearly gave the worst results in almost all respects. Ploughing and ripping both gave the best results, with no distinct difference betwen these two treatments (Lungu and Matakala found the same results in 1988). Growing maize on ridges seemed to perform slightly less. This general line roughly corresponds with the results found by Gill, et al (1985) in a comparable experiment.

Research of Lenvain (1987) indicates the probable reason for the disappointing results of no-tillage. He found that this particular type of soil has unfavourable water conduction and intake properties, especially in the top layer. Mullins and Sinclair (1986) explained that the structure of the surface horizon easily collapses. Clay and silt fill the gaps between the sand grains. Such a compact top layer, as present on non-tilled fields, has a low water intake rate and a relatively high hydraulic conductivity. This was actually observed by Lenvain. He measured a water intake of 56 mm during the first week of heavy rain on a newly tilled plot, while only 19 mm infiltrated on a non-tilled plot. During the subsequent dry spell water losses were 16 mm/week on the non-tilled plots, and only 7 mm/week on tilled plots.

Conclusions

The experiment confirms that tilling the soil is just as important as the question of how it is exactly tilled. All three tillage methods gave much better results than the no-tillage system. Especially ploughing and ripping performed quite well.

The use of a ripper tine looks promising. Preparing the soil before planting requires far less time than ploughing: only one passage is needed for every plant row while ploughing would require three or four passages. Ripping as a main tillage method deserves more attentioin in tillage research in Zambia (or Southern Africa), for the benefit of the small scale farmer.

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(Continued from page 33)

An Experimental apparatus for Simultaneous Spreading of Plastic Mulch and Drip Irrigation Pipes

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Development of Low-cost, Hand-operated Planter

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Abstract

A low-cost, hand-operated planter (herein identified as Magulu hand planter) has been designed and developed at the Department of Agricultural Engineering in Morogoro.

The design involved the development of a seed planter attachment which can be fastened to a typical hand-hoe and can be used to plant both maize and beans in a straight row.

Field tests were conducted to study the performance of the planter. It was shown that the Magulu hand planter has a work rate of between 18 man-hours per hectare and 27 man-hours per hectare as compared to 80 man-hours per hectare when using conventional hand-hoe planting method.

The discussion leads into a conclusion that the Magulu hand planter is an appropriate farm tool for peasant farming in relieving a farmer from the drudgery of planting operation.

Introduction

The hand-hoe is the most commonly used implement under peasant farming in many developing countries, including Tanzania. It is used in a wide range of soil types and field operations ranging from primary tillage, planting, weeding and harvesting of root and tuber crops.

The length of the hoe handle and hoe design (eyed or tanged) depends on the local tradition but, in general, long handles and heavy heads give deeper work during tillage operation. However, under other working conditions, for example, in weeding, where the operator has to use his hands in the soil, short hoe handles and light heads are preferred.

Very little research has been conducted to ascertain the work output and efficiency of using a hand-hoe under different soil and climatical conditions. However, the maximum output under any condition will be limited to the power capability of a healthy human being, which stands at about 0.1 kW.

For field operations such as primary tillage, weeding or harvesting, one person per hoe is required. For planting operation however, two or more people are required per hoe. In order to plant at recommended spacing, a typical planting exercise (for maize) will normally involve digging holes at 30 cm interval within the row, applying one "soda" cap of fertilizer per hole, covering the fertilizer with soil, placing seed in a partially filled hole and finally covering the seed. Farmers are urged to use a rope or a 75 cm and 30 cm sticks as a guide for straightening rows and maintaining the between- and within-row spacings. On average, three people are required to carry out these processes in one run.

The novel idea described here is directed towards solving the above-mentioned problem in planting, which necessitates the need for two or more people or two operations. This is done by including a planting attachment device on the hand-hoe which combines several processes required in the conventional hand-hoe planting and thus providing a faster and easier planting method for farmers.

Design and Development of Magulu Hand Planter

Description and Specification of Planter

Figure 1 is a sketch of the developed planter while **Fig. 2** is a blown-up (exploded) diagram of the hand planter. The planter consists of a normal hand-hoe, a normal wooden handle, a seed hopper with separate seed and fertilizer compartments, a seed metering device, side and front markers and a control string/rot. The metering device contains a seed cell, a return spring and a guide box which is welded to the base of the hopper and is part of the seed hopper.

Three planter's attachments of different sizes and capacity were made for field evaluation. The capacities of these planters are summarized in **Table 1**, while the planters' components and their design specifications are summarized in **Table 2**.

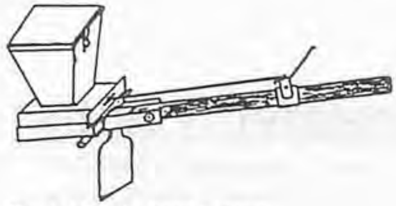

Fig. 1 Magulu hand planter.

Table 1 Capacities of Designed Planters

Planter design no.	Capacity (cm³) Seeds	Fertilizer	Net weight Empty (kg)	Gross weight Full (kg)
1	0.64	0.91	4.50	6.19
2	1.09	1.55	4.64	7.28
3	1.20	3.12	5.14	9.44

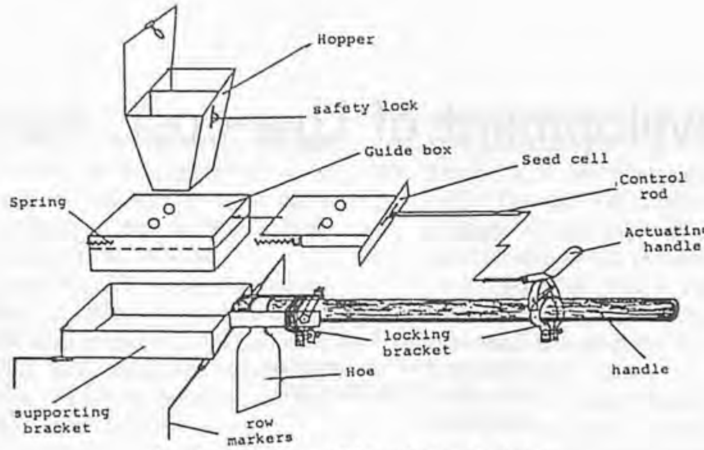

Fig. 2 Main parts of Magulu hand planter.

Table 2 Planter's Components and Design Specification

Component	Specification	Capacity/Weight	Cost
Hoe	UFI small size hoe	1.23 kg	220/=
Hopper	2 mm steel sheet 3 sizes were made		
Size 1	Top: 16 cm × 16 cm base: 6 cm × 6 cm	2.07 kg	680/=
Size 2	Top: 20 cm × 20 cm base: 6 cm × 6 cm	2.20 kg	720/=
Size 3	Top: 24 cm × 24 cm base: 6 cm × 6 cm	2.62 kg	800/=
Guide box	Rectangular box 2 mm steel sheet with 2 holes at the top. 10 × 8 × 45 cm	—	85/=
Seed cell	Rectangular box 2 mm steel sheet with 2 holes to meter seeds. 10 × 8 × 1 cm	—	75/=
Supporting bracket	5 mm steel bar. To hold guide box and hopper to hoe handle	—	90/=
Bolts and nuts	2 M8		50/=
Control rod	3 mm steel wire and 0.6 m long	—	20/=
Actuating handle	To pull seed cell so as to align holes with hopper & meter seeds	—	30/=
Row markers	4 mm steel rods to mark required spacing	—	70/=
Hoe handle	Wooden handle approx. 1.3 m long	—	50/=
Return spring	light coil spring to retract seed cell after each operation	—	80/=
Safety lock	To lock the hopper cover securely	—	50/=
TOTAL APPROX. COST (excluding labour)... (based on 1988 prices; 1 U$ = 90/Tshs)			Tshs .1620/=

Principles of Operation of Planer

At the start of the operation, the return spring positions the pick-up holes on the seed cell in line with the top holes on the guide box **(Fig. 2)**. In this position, seeds and fertilizer drop under gravity into the pick-up holes aided with the impact forces generated on the hand-hoe during the digging (for furrow opening) operation. The number of seeds and amount of fertilizer metered into the seed cell pick-up holes is governed by the size of these holes. For the prototypes discussed in this paper, the size of the holes were 10 mm height and 16 mm in diameter.

After opening the furrow in the soil, the seeds and fertilizer are already metered into the pick-up holes in the seed cell. The actuating handle is then pushed down, and this pulls the seed cell through the control rod and aligns the pick-up holes on the seed cell with the bottom holes on the guide box. In this way seeds and fertilizer are allowed to drop into the furrow at their required points. On releasing the handle, the spring pulls the seed cell back to its resting position ready for the next operation. The marks made by the markers during the cutting action are used by the operator as a guide for the next furrow opening operation and thus seeds can be planted in straight rows.

In summary, the following operations can be combined in one run by one operator: Opening of the furrow, metering seeds and fertilizer into the furrow, covering the seeds and fertilizer in the soil and marking to obtain the required between- and within-row spacing.

Field Experiments

Materials and Methods

The hand planter was tested at the Sokoine University farm in Morogoro. The test plot was ploughed by a tractor and was then subdivided into two main blocks. One of the blocks was used to measure work rates for conventional hand-hoe planting method and the other was used to measure the work rate for the Magulu hand planter. Five people of different capabilities, sex and age were used to determine the work rates and to identify the suitable and convenient hopper size to work with.

The block used for testing the Magulu hand planter was subdivided into five plots of 620 m^2 which were randomly allocated one to each of the five people. The block used for conventional hand planting was divided into two plots and three people were allocated to each of the two plots; one doing the digging, the other dropping the seeds in the opened furrow and the last one placing fertilizer and covering the furrows.

The main objectives for the tests are presented in the section below, while the results are summarized in **Table 3**.

Table 3 Work Rates: Conventional Planting and Magulu Planter

Method of planting	Group/person involved	Man-hours per acre	Man-hours per ha
Conventional hand-hoe planting	Group 1	36	90
	Group 2	29	72
Average conventional method		33	81
Magulu and Planter	Young man less than 20 years	18.3	45.8
	Young man more than 20 years	10.7	26.8
	Adult man more than 30 years	6.9	17.3
	A lady more than 20 years	15.2	38.0
	2nd lady more than 20 years	15.2	38.0
Average for Magulu planter		13.0	33.0

Table 4 Quality Performance of Magulu Planter

Parameter observed	Magulu planter	Conventional planting
Average within row spacing (cm)	28-32	Without rope: 30-40 with rope: 30
Average depth (cm)	12-15	10-12
Fertilizer application rate (g)	195 gm	sodas cap
Application rate of maize (in % of total maize planted)		
: missed the hole	10%	—
: 1 seed per hole	29%	—
: 2 seeds per hole	36%	—
: 3 seeds per hole	18%	—
: 4 seeds per hole	4%	—

Objectives of Field Tests

The objectives for the field tests were:

(a) To assess the quality performance of the Magulu hand planter with respect to:
- Number of seeds dropping per hole;
- Amount of fertilizer applied per hole; and
- The accuracy and maintenance of planting spacing (between and within row spacing).

(b) To determine the work rates for the Magulu hand planter and to compare it with the work rates in conventional hand-hoe planting method. And hence determine operator performance.

(c) To observe the soundness of design, control and any other construction defects of the Magulu hand planter.

Field Test Results

Table 3 is a summary of results showing the comparison of work rates between the conventional hand-hoe planting method and the Magulu hand planter.

Discussion and Conclusion

The field test results reveal that the Magulu hand planter has a work rate ranging between 17 man-hours per hectare and 46 man-hours per hectare (depending on the user), as compared to approximately 80 man-hours per hectare when using a conventional hand-hoe planting method. Using the Magulu planter therefore, one person can plant an acre comfortably within a day as compared to three days for an acre in the conventional hand planting method.

Assessment of the planter's controls and reliability was done subjectively. It was found that the operators could easily adapt themselves to the controls and sequence of operation. During the field tests, it was observed that the physical effort required to operate a medium and large planters (designs 2 and 3) appeared to be on the high side. This was due to the gross weight of the planters. It was, however, noted that a 20 × 20 cm hopper size planter (design no. 2) was the most suitable size and handy for an adult in good health to work with.

The overall performance of the Magulu planter was good as compared to the conventional hand-hoe planting method. The inter-row and within-row spacing was easily controlled by the use of the markers. The amount of seeds and fertilizer dropping per hole was within the recommended application rate of two seeds per hole and about 195 g of fertilizer. However, further improvement on the planter and field evaluation is called for so as to ascertain the performance of the planter under different soil and climatical conditions.

It would also seem appropriate for future planters to be made out of lighter material such as tin or aluminium to reduce the manufacturing cost and provide a lighter planter to work with.

In summary, the Magulu hand planter has the following main attributes:
- Reduce labour requirement during planting operation.
- Provides a faster and easier planting method.
- Utilizes local available construction materials.
- Is low cost technology and easily adapted.

With encouraging results produced, the Magulu hand planter is seen as an appropriate tool for peasant farming in developing countries, especially in relieving a farmer from the drudgery during planting operations.■■

Agricultural Machinery Testing in India

by
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Introduction

Farm mechanization in India has been one of the outstanding developments during the past two decades and has contributed significantly to land productivity, efficient crop management, and post-harvest handling of farm products. The burden and drudgery of farm work has been reduced and the output per worker has increased considerably.

The introduction of tractors started in Indian Agriculture with imports in 1940s. But it picked up in 1950s when a number of brands of tractors were imported. Until 1960, India had to depend upon imported tractors and the evaluation of the performance of the imported tractors was known mostly from their field performance at the Central Tractor Organization and farm mechanical cultivation shemes of the different States. The tractor production per year which was 3877 during 1961-62 rose to 80 004 during 1986-87, which is expected further to increase substantially. Presently, around 14 firms are manufacturing 39 models of tractors ranging from 14 to 60 pto H.P. Similarly, a large number of industries are manufacturing agricultural implements and their production is also likely to increase mainfold in future. Thus today we see a variety of tractors and other agricultural machines going from research institutes and manufacturers to the consumer. But their success in the field can be achieved through quality control which means ensuring that the machine supplied to the customer must have functional and endurance reliability. The wide variation of soil and climatic conditions, agronomical practices and crop rotation in different parts of the country may make one machine useful in one area but useless in another area.

Thus the field of tractor and other farm machinery testing is most important and presents a greater challenge in achieving quality control and standardisation. In the light of urgent need for testing of agricultural machines and tractors by an impartial agency, the Government of India took a decision to institute a Tractor Testing Station in order to check the suitability of performance of tractors and other allied machines before taking decision of importing or manufacturing them in India. This station initially came into existance at Nagpur and then finally established at Bundi (M.P.) in 1959. Subsequently, considering the increasing need of such services, the Government approved two testing sub-stations in other parts of the country during 1972 and 1983.

Establishment of Testing Institutes

Testing by an impartial agency is the most reliable criteria in judging performance. Thus to test tractors, implements, stationary engines, pump sets, plant protection equipment, combine, harvesters and other farm machinery with a view to assessing their performance characteristics in the laboratory as well as under actual field conditions, the Government established three testing institutes in different parts of the country, namely:

1. Central Farm Machinery Training and Testing Institute, Budni (M.P.)
2. Northern Region Farm Machinery Training and Testing Institute, Hissar (Haryana)
3. Southern Region Farm Machinery Training and Testing Institute, Garladinne (A.P.)

These institutes are operating to meet the following specific objectives:

a) to serve as a basis for deciding the type of machine best suited for Indian agro-climatic conditions which could be encouraged for import, production and popularisation;
b) to help the farmers, prospective purchasers and government agencies in determining the comparative performance of machines available in the market;
c) to provide information to the extension workers for advising farmers and other interested purchasers in proper selection

of the equipment;

d) to form the basis for standard specification to be used by manufacturer and distributors;

e) to provide suggestion for effecting further upgrading of quality of the products by the designer/manufacturer;

f) to help financial institutions in providing credit assistance to the purchasers for quality products;

g) testing under B.I.S. certification Mark scheme for several farm machines and equipment; and

h) to evaluate farm machines and implements from other countries with a view to examining the possibility of their introduction in the country and vice-versa for export purposes.

Testing Activities

The following types of regular tests are conducted on tractors, power tillers and agricultural machinery:

Confidential Tests

Confidential tests are meant for providing confidential information on performance of machines which are required for commercial production or to provide any special data that may be required by the manufacturer/applicant. The following categories of machines are covered under the scope of confidential tests:

i) Prototype machine before it is ready for commercial production.

ii) Improved machine prior to its progressive manufacturing/import on large scale.

iii) Machines under commercial production but with modification of one or more systems for improved performance.

iv) Machines submitted for test under B.I.S. (Bureau of Indian Standards) Certification Mark Scheme.

Confidential test report cannot be used for any commercial purposes. The applicant is not permitted to publish confidential test reports in full or in abbreviated form or to divulge the test results contained therein to any person or body.

Commercial Tests

The commercial test are conducted on machines which are intended or ready for commercial production in order to establish their performance characteristics. The following types of commercial tests ar undertaken:

i) Initial commercial test:
On indigenous or imported prototype machine ready for commercial production.

ii) Batch test:
In the context of the need for continuous improvement in the quality of the machines produced in the country, the machine under series production is tested after a certain time interval. At present this is applicable to tractors only which are tested after a lapse of every two years.

iii) Series test:
Series test provides testing of large number of samples, simultaneously under identical conditions to have comparative performance of similar machines for the guidance of users, manufacturers and extension agencies.

iv) Test as per OECD Code:
This is done on machines (which have already undergone initial commercial test) on specific request of the applicant/manufacturer exclusively for export purposes. Commercial test report can be published in full without any alteration or omission by the applicant, However, the extract or abbreviated version of the test report cannot be published by him.

v) Users survey:
This forms an essential component of batch testing programme and designed for assessing the general performance, field complaints and durability of the machine in use with the farmers and user organisations. It also provides information on standard and number of after-sales service facilities provided by the manufacturer and its dealers network.

Application of Standards and Procedure

With the increasing emphasis on farm mechanisation to boost agricultural productivity, the machines have to render reliable service under varying agro-climatic conditions. Easy operation, maintenance, availability of spare parts and interchangeability of critical components assume special significance in the rural sector where basic infrastructural facilities for repairs and maintenance are lacking. To promote the acceptance of the agricultural machinery as a whole, the Bureau of Indian Standards developed and made available Indian standards on majority of the machines/components covering farm power and machinery used in the country. Testing of particular machines is done as per relevant Indian Standard. In case Indian Standard has not been formulated for any particular machine, test code and procedure suitable to the requirements is prepared by the Testing Authority and the same is used for testing purposes.

India has also become member of the Organisation for Economic Cooperation and Development (OECD). The Central Farm Machinery Training and Testing Institute, Budni (M.P.) being the

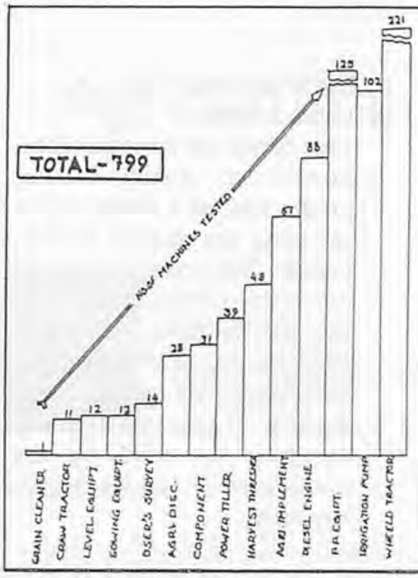

Fig. 1 Machines tested in various category.

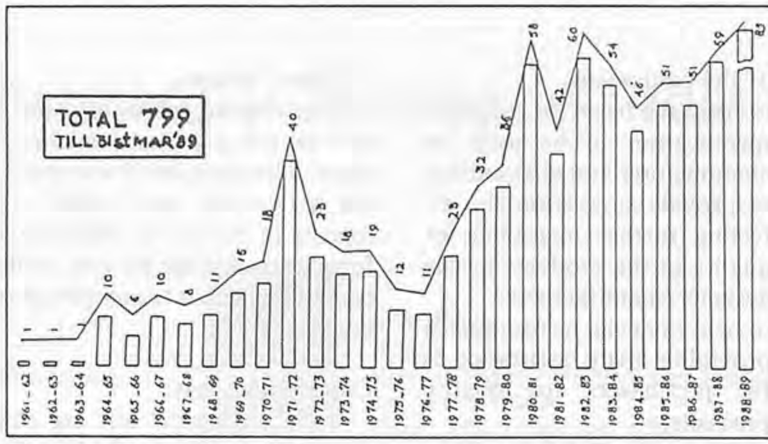

Fig. 2 Machines tested year-wisse.

Table 1 Population of Tractor and Agricultural Implements

Units: 1000

Item	1966	1977	1988 (Est.)	% increase (1988/1966)
Tractors	54	276	850	1474
Seed drills	34	4927	5600	16371
Power threshers	349	484	1500	330
Iron plough	3523	6515	6800	93
Irrigation pumps	886	6670	9000	916
Plant protection equipment	211	633	2450	1061

operating agency for this purpose, is authorised to test tractors as per OECD Test Code.

The testing of any machinery is done under the framework of "Regulations for Testing of Agricultural Machinery" as approved by the Government of India.

The requisite for submission of machine for test:

1. Submission of application in triplicate in the prescribed format along with specifications and literature of the machine to the concerned testing authority by the applicant.
2. Acceptance of machine for test by the testing authority.
3. Deposit of advance towards testing charges by the applicant.
4. Random selection of test sample if applicable under test regulation or as the case may be.
5. Sumbission of test sample by applicant to the testing authority.

Progress in Testing of Farm Power and Machines: After completion of tests and analysis of data a Test Report is relased to the applicant.

Up to March, 1989, the testing institutes have tested and released 799 test reports on various types of agricultural machines (**Fig. 1**). Whereas yearwise progress for testing of agricultural machines has been shown in **Fig. 2**.

Impact of Testing on Production and Popularization of Agricultural Machinery: Through constant improvement of tractors and agricultural machines, the acceptability and reliability of these machines have been increased considerably, which has lead to tremendous increase in growth of farm machinery (**Table 1**) as well as industries manufacturing agricultural machines.

Conclusion

To safeguard the user's interest in obtaining quality product and also for the growth of farm machinery industry, there is need for testing of the product at various industry and institutional levels. Testing must be done by adopting standardised procedure and by using up-to-date instrumentation and methodology so that test results will have the characteristics of repeatability. The testing done by an impartial testing agency has unquestionable validity. This will be a step forward for providing quality and trouble-free machines to farmers for making farming practices as a pleasant job for increasing agricultural production.

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Laboratory Method for Determining Energy Requirement for Pulverizing Soil Clods

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Abstract

The energy required to pulverize soil clods to different degrees of fineness was studied in a laboratory experiment with sandy loam and sandy clay loam clods under different moisture regimes. The clods were loaded under compression. Energy input was determined from an x-y plot obtained during loading. A nest of sieves was used to measure the degree of pulverization.

A higher degree of size reduction was observed in the lower moisture regime in both types of clods. The higher bulk density clods among the wet group were more pulverized for the same level of break up at the early stage, then a decline and even compaction in one case was observed. A proportional increase in surface area with increase in energy input was marked in the medium moisture regime (16-21% m.c.), particularly in the sandy loam clods. Deviation from linearity both at low and high moisture conditions was observed in the sandy clay loam group.

For the range of soil types and conditions tested, it can be inferred that finer seed-bed could be effected at a low input of energy in the drier condition, whereas operation in the wet regime would result in cloddy seedbed even at high input of energy.

Introduction

Tillage is an energy-intensive operation. If we select the kind of seedbed suited for the particular crop, thereby the degree of soil pulverization and the implements to effect it, we will be able to conserve energy, as well as reduce the cost of production.

In Ethiopia, conventional tillage consisting of three to four ploughings using "maresha"* is the usual practice for the production of most crops, despite variation in soil type, rainfall and cropping pattern. The conventional tillage practice exposes the soil to erosion, and the cost incurred in terms of energy is high. Different crops need different types of seedbed which implies that conventional tillage practice of ploughing followed by harrowing may not be ideal for all crops. Small grains like wheat need a fine seedbed while others like maize may do well in coarser ones. Excessive ploughing in light soils will expose the soil to erosion and in such conditions tillage will not meet the objective. The development of injector planter and herbicides has made it possible to sow seeds without ploughing the land which is helpful for places threatened by soil erosion. This shows that tillage operation should be adjusted to suit the objective situation and the implements must be selected accordingly. The energy utilization efficiency measured by the degree of breakup of the soil as related to the requirement of the plant is one aspect which should be looked into if we are going to operate cost effectively and minimize soil degradation.

Objectives

The main objective of the study was to determine the energy required to pulverize soil clods of different moisture content levels and varying bulk density in the laboratory. It also looked into the effect of particle size distribution and carbon content on the degree of pulverization. Also, the optimum condition for seedbed prepa-

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*Ethiopian ard which does not invert the furrow slice but makes a V-shaped furrow instead.

ration was considered.

Theoretical Consideration

The specific energy required to reduce the aggregate size of the soil is inversely proportional to the mean aggregate diameter obtained.

$DE/db = ab^n$

where,

E is energy

b is mean aggregate diameter

a and n are constants (4)

The energy expenditure is linearly related to the specific surface area produced.

$E_{D_2} - E_{D_1} = a_e/6\ (A_2 - A_1)$

where,

D_2 and D_1 diameter

e density

A_2 and A_1 surface area (4)

Literature Review

Some related works have been done by different researchers. Gill and McCreery[3] developed the drop shatter impact type test to determine the equivalent energy required to pulverize soil clods to different degrees of fineness. Hadas and Wolf[4] have come up with a new approach to the drop shatter impact wherein they took the terminal velocity into account. Kirkham, Molden Hauer and Rogowski[5] showed that rapture stress was highly correlated with both aggregate bulk density and the clay content. Beteman, Naik and Yoreger[1] have studied energy of pulverization on a mould of 6 inch cubes both by impact loading and slow loading methods under different levels of compaction. Van Bavel[7] has described a graphical method of determining the mean weight diameter (M.W.D.) of aggregates. A short method of obtaining the M.W.D. has been developed by McGuineess and Yoreger[6]. Ellen[2] studied the energy requirement for the pulverization both on volume and area basis.

Material and Methods

Soil clod samples for the experiment were collected from two sites at Naferton Farm. The clods from each site were collected in three plastic bags making the selection in such a way as to have three moisture regimes represented. The samples were left in the bags for some time to help the moisture creep through the whole sample minimizing the moisture variability within the sample.

The apparatus included a nest of sieves of size 9.525, 4.74, 3.55, 2.00, 1.18 and 0.425mm and a tray for measuring the degree of soil break up, a graduated cylinder of 100 ml for measuring the volume of the clod, a thin polythene bag and a yarn of thread for wrapping the clods to stop water from creeping through while measuring the volume, a caliper to measure the size of the clods and a balance for weighing purpose. The loading apparatus used was a tensile testing machine with a 5 kn load cell and a compression cage accessory for conducting compression test and an x-y plotter for plotting the load against the displacement.

At the beginning of the experiment, the sieves were weighed and arranged in ascending order. Soil samples from the bag were put in three pre-weighed tins and the moisture content was determined by gravimetric method. A clod from the same batch was taken and weighed. Its size was measured using a caliper and the second largest size recorded as the original size (d) of the clod. The clod was put in the polythene bag and wrapped with the thread so that the discrepancy in volume between the wrapped clod and the clod proper was minimized. The volume of the clod was determined by displacement method. The clod was unwrapped as gently as possible and placed on aluminium foil tray and put into the machine. The loading rate on the machine was adjusted to the 20mm/min mark and the paper cross head ratio was set at 2.5/1. Both of these were found to give reasonable reading after some trials before the actual experiment was conducted.

After the necessary adjustments were made the loading was started by switching on the machine. An eye was kept on the x-y plotter making sure that the experiment is stopped before a steep gradient started to appear in the plot which indicated compaction rather than pulverization. Then the pulverized soil was put into the upper sieve and the sieves were gently tapped to make the pulverized soil pass to the appropriate sieve, care being taken not to break aggregates which were not broken by the operation. Each sieve with the retained soil was weighed and the difference between the new weight and the sieve weight was recorded as the percentage by weight of the total in each diameter class. The size of the largest clod in the largest diameter sieve was measured to give the range of that diameter class. After these data were taken the soil was put back into the cylinder and the whole operation was repeated from three to five times until a reasonable degree of fineness in the break up of the clod was achieved. The mean weight diameter (M.W.D.) was calculated by the formula developed by McGuiness and Youker[6].

$Y = 0.876X - 0.079$

where,

Y represents the M.W.D.

X represents the product of the midpoint of each diameter class and the percent retained in each diameter class sieve

In order to determine the energy, the plot from the x-y plotter was digitized using a digitizer which directly put it into a file. Then a small computer programme was written to calculate the energy as an area under the plot using the trapezoidal rule. The programme used the digitized data from the file to calculate the energy.

A mechanical analysis was done to determine the soil texture. For the fine analysis, the pippette method was adopted.

The carbon content of the soils was also determined using a carbon-surfur analyser.

After the mean weight diameter and energy were calculated as described above, to make comparison easier the energy of pulverization was calculated both on specific volume and area bases. Also, the increase in surface area as related to the energy input was determined.

Results and Discussion

General

An increase in energy input is observed to be generally associated with a decrease in the mean weight diameter. In the medium moisture regime, the specific energy input is more or less linearly related to the increase in surface area. Deviation from linearity is observed both at the high and low moisture regimes.

Effect of Moisture

A higher increase in surface area is observed in the drier clods at the same level of energy input compared to the wet clods.

Effect of Bulk Density

It is not only the moisture content but also the bulk density that influences the ease of break up of the clods. In the dry clods, lower bulk density made it easier for an increase in surface area as compared to the high bulk density group. In the high moisture group, the clods with higher bulk density tend to fracture rather than the clods with a lower bulk density which tend to compact.

Effect of Soil Type

Though the experiment was conducted with two soil types, still certain factors could be explained in light of the textural class. Among the sandy loam groups, two of them turned out to be sandy clay loam. In this group the 17.35% moisture clod showed

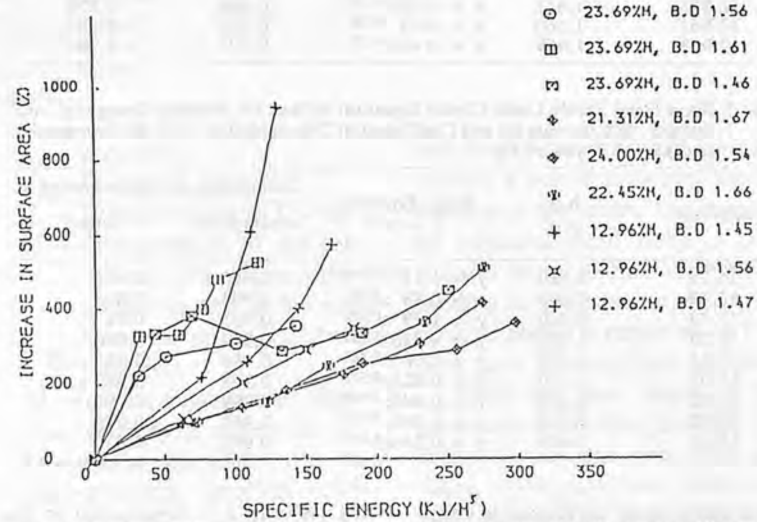

Fig. 1 Sandy clay loam soil: Increase in surface area as related to energy input.

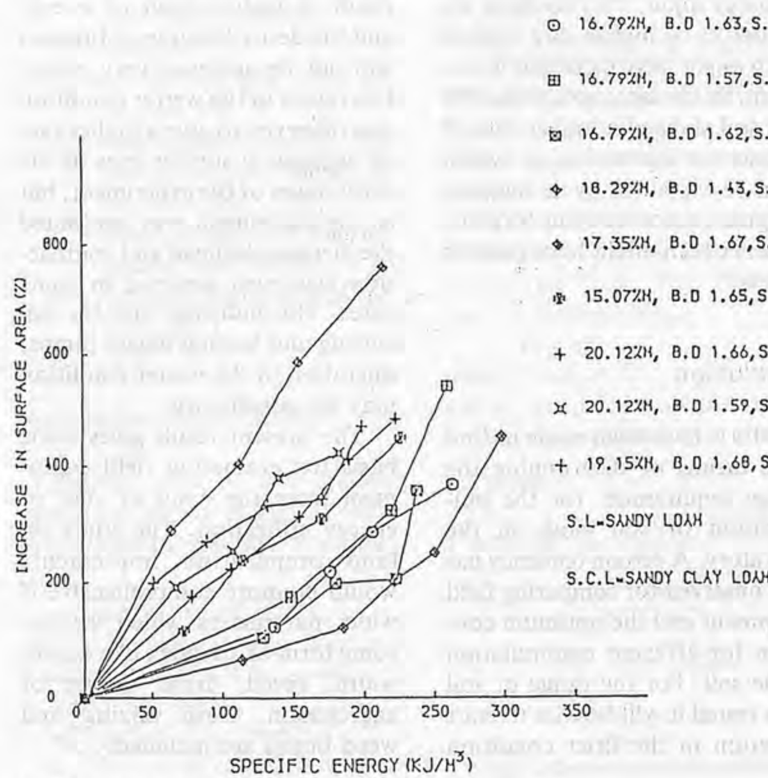

Fig. 2 Increase in surface area as related to energy input.

Table 1 Foxcover Sandy Clay Loam Clods: Equation of Best Fit Relating Energy (y) and Surface Area Increase (x) and the Coefficient of Determination for Both Exponential and Linear Types of Fit

Moisture	b.d. g/cc	Regr. Equation $y = ax^b$	Coefficient of determination	
			exponential r^2	linear r^2
23.690	1.560	$y = 0.131x^{1.108}$	0.970	0.737
23.690	1.605	$y = 0.092x^{1.098}$	0.989	0.872
23.690	1.461	$y = 0.119x^{1.16}$	0.953	0.486
21.306	1.678	$y = 0.651x^{1.018}$	0.998	0.985
24.000	1.537	$y = 0.669x^{1.027}$	0.998	0.969
22.450	1.660	$y = 0.763x^{0.973}$	0.996	0.970
12.963	1.451	$y = 0.380x^{0.895}$	0.986	0.850
12.963	1.560	$y = 0.59\ x^{0.98}$	0.999	0.997
12.963	1.469	$y = 0.418x^{0.97}$	0.997	0.947

Table 2 Shop Front Sandy Loam Clods: Equation of Best Fit Relating Energy (y) and Surface Area Increase (x) and Coefficient of Determination for Both Exponential and Linear Types of Fit

Moisture	b.d. g/cc	Regr. Equation $y = ax^b$	Coefficient of determination	
			exponential r^2	linear r^2
16.79	1.630	$y = 1.137x^{0.937}$	0.995	0.958
16.79	1.568	$y = 0.88\ x^{0.94}$	0.994	0.895
16.79	1.620	$y = 1.29\ x^{0.936}$	0.991	0.84
18.29	1.430	$y = 0.218x^{1.029}$	0.999	0.990
17.35	1.670	$y = 1.98\ x^{0.880}$	0.980	0.823 s.c.1
15.07	1.650	$y = 0.621x^{0.971}$	0.998	0.989 s.c.1
20.12	1.658	$y = 0.445x^{1.008}$	0.999	0.997
20.12	1.590	$y = 0.346x^{1.021}$	0.998	0.978
19.15	1.685	$y = 0.248x^{1.077}$	0.993	0.927

lower increase in surface area than the other clods for the same level of energy input. This could be attributed to its higher clay content which might have increased its cohesion. In the same group 18.29% m.c. soil showed a higher rate of increase in surface area which could be explained by its relatively higher carbon content (organic matter) which might have made it friable.

Conclusion

Efforts have been made to find some means of determining the energy requirement for the pulverization of soil clods in the laboratory. A certain tendency has been observed for comparing field equipment and the optimum condition for efficient manipulation of the soil. For the range of soil types tested it will be wise to start operation in the drier condition (12-16% m.c.). Operation in the higher moisture range (22%) will result in higher input of energy and the desired degree of fineness will not be achieved very easily. Operation in the wetter condition was observed to give a higher rate of increase in surface area at the early stages of the experiment, but as the experiment was continued the increase declined and compaction was even detected in some cases. This indicates that for soil cutting and leaving bigger lumps, operation in the wetter condition may be satisfactory.

The present result gives some basis for evaluating field equipment from the point of view of energy utilization. The study on land preparation implements would be more comprehensive if wider parameters which lead to some form of an index like depth, width, speed, draft, degree of aggregation, trash mixing and weed burial are included.

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Mathematical Model of Rice Huller's Rubber Rolls

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Abstract

A spatially one-dimensional, mathematical model to analyse the effect of roller speed, mass, radius and friction coefficient is presented. The model assumes that paddy is fed in such a way that two of them do not touch side to side between the rolls. The model is used to simulate the relationship between the coefficient of friction of the rubber and the moment of inertia of the rolls.

Introduction

Rice processing technology depends to a large extent on the hulling quality, which is very much determined by the quality of the hulling surfaces. The hulling surface also has a quality level which is determined by the dynamic friction coefficient of the material it is made of. Effort is made here to show the relationship between the dynamic friction coefficient of the rubber material and other pertinent parameters.

Nomenclature

- F_r —radial force (N)
- I —moment of inertia (kg-m^2)
- α —momentary relative angular deceleration due to the presence of rice (radians/sec^2)
- F_f —frictional force (N)
- K —Rubber stiffness (N/m)
- X —Compression of the rubber on each roll, assumed along the axis of the rubber and equal on both rolls (m)
- M —mass of each roller (kg)
- v —velocity of roller (m/s)
- r —radius of roller (m)
- μ_k —dynamic friction coefficient
- θ —angle moved through by the roller (radians)
- F_h—hulling force
- F_g—rubber roll grip force on the rice (N)
- F_c—centripetal force on the rice due to the rotation of the rolls (N)
- σ_p—shear strength of the rice paddy husk (N/m^2)
- A —cross-sectional area of the husk (m^2)

Rice Huller Rolls Model

Rubber rolls of rice hullers operate as shown in **Fig. 1**. Both rolls rotate in opposite directions and the gap between them is varied in such a way that depending on the size of the grain, the gap can be adjusted until there is just enough force to hull the paddy. Hulling is a process in which the husk of paddy is removed by friction, here between two rollers.

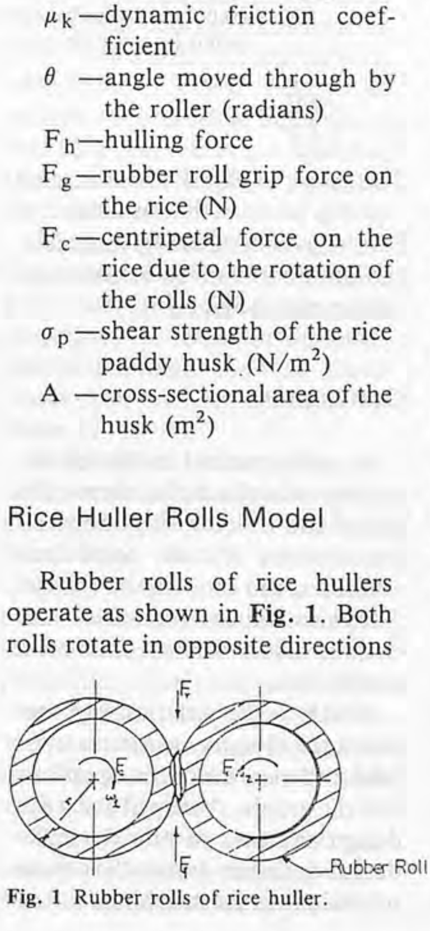

Fig. 1 Rubber rolls of rice huller.

There are two major forces governing the hulling process, i.e., radial force and the frictional force. The radial force pushes the grain through the gap between the rolls while the frictional force hulls the paddy.

The radial force $F_r = \frac{I\alpha}{r}$ (1)

For each of the rolls this becomes

$F_{r2} = I_1\alpha_1$ and $F_{r2} = I_2\alpha_2$ (2)

Assuming the use of the same rolls

$I_1 = I_2$ (3)

The frictional force opposes the radial force causing the shearing of the rice husk. This frictional force is derived from

$F_f = \mu F$ (4)

where $F = F_g + F_c$ (5)

and F_g (grip force of the rubber on the rice) $= k_x$ and F_c (centripetal force) $= \frac{MV^2}{r}$ (6)

Therefore, $F_f = \mu_k\left[k_x + \frac{MV^2}{r}\right]$ (7)

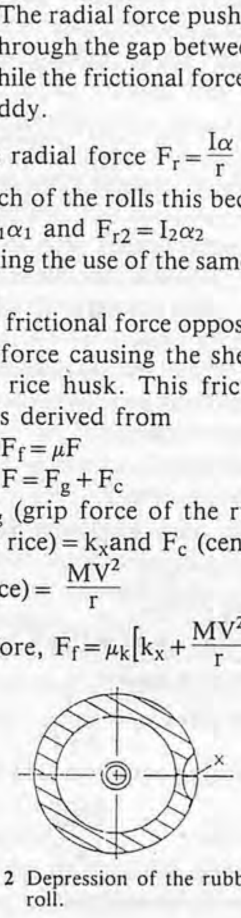

Fig. 2 Depression of the rubber roll.

For each of the rolls

$$F_{f1} = \mu_{k1}\left[k_1 x_1 + \frac{M_1 V_1^2}{r_1}\right] \quad (8)$$

$$F_{f2} = \mu_{k2}\left[k_2 x_2 + \frac{M_2 V_2^2}{r_2}\right] \quad (9)$$

Assuming that the rolls are the same, equations (8) and (9) becomes

$$F_{f1} = \mu_k\left[kx_1 + \frac{MV_1^2}{r}\right] \quad (10)$$

$$F_{f2} = \mu_k\left[kx_2 + \frac{MV_2^2}{r}\right] \quad (11)$$

Resultant frictional force $F_{fr} = F_{f1} + F_{f2} = \mu_k\left[K(X_1 + X_2) + \underline{M}\,(V_1^2 + V_2^2)\right]$ (12)

assuming $X = X_1 = X_2$ and $V_1 = \omega_1 r$ and $V_2 = \omega_2 r$ that is the compression of the rubber on each roll is not too different, then

$$F_{fr} = \mu_k\left[2KX + \underline{Mr}\left[\omega_1^2 + \omega_2^2\right]\right] \quad (13)$$

But the resultant frictional force opposes the radial force giving a hulling force of

$$F_h = F_r - F_{fr} = \frac{I}{r}(\alpha_1 - \alpha_2) - \mu_k\left[2kx + M_r(\omega_1^2 + \omega_2^2)\right] \quad (14)$$

$$F_n = I/r\ (\alpha_1 - \alpha_2) - \mu_k\left[2kx + M_r(\omega_1^2 + \omega_2^2)\right] \geqslant N\sigma_p A \quad (15)$$

where,

N —number of rice seeds in between the rolls at a time

σ_p —yield strength of rice paddy husk.

A —cross sectional area.

also assuming $\omega_1 = f\omega_2$ where f is the speed ratio

$\omega = \omega_2$

and $\alpha = \alpha_1 - \alpha_2$

Then $F_n = I\alpha - \mu k\left[2kxr + M_r^2 (1 + f^2)\omega^2\right]$ (16)

using $I = M_r^2$

$$F_n = I\left[\alpha - \mu_k(1 + f^2)\omega^2\right] \geqslant N.$$

$$\sigma_f.A + 2\mu_k kxr \quad (17)$$

This gives $\mu_k = \dfrac{1}{1 + f^2}$ (18)

Substituting equation (18) in (16) gives

$$F_n = I(\alpha - \omega^2) - \frac{2kxr}{1 + f^2} \geqslant \sigma_p.A.N.$$

of $F_n = M_r^2(\alpha - \omega^2) - \dfrac{2kxr}{1 + f^2} \geqslant \sigma_p.A.N.$

The graph in **Fig. 3** shows a relationship between the variables r, k f and m which the design engineer can decide to vary to achieve optimum performance.

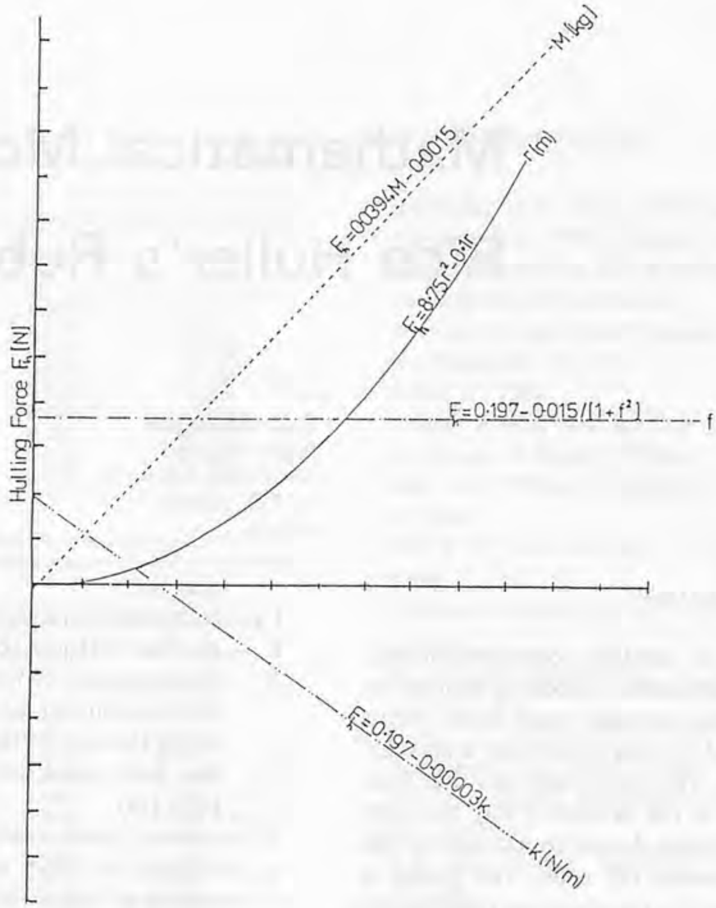

Fig. 3 Hulling force against speed ratio (f), rubber stiffness (k), roller radius (r) and roller mass (kg).

Conclusion

A mathematical model of the rubber rolls rice huller shows the significant relationship between the dynamic friction coefficient and the speed ratio of the rollers. This also implies the speed that can be used for each friction coefficient.

Finally, the relationship between the design parameters is established in terms of the equations and the graphs. This will assist the design engineer to quickly make design decisions during the course of designing the machine.

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Development of 4-ton Paddy Dryer

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Abstract

A 4-ton paddy dryer suitable for small scale farmers' group in Southeast Asia was developed and tested at the International Rice Research Institute in the Philippines. The dryer using rice hull as fuel requires low labour input.

Drying paddy on pavements or highways results in poor quality rice and is labor intensive. The development of a dryer suitable for small scale farmers' group offers a better alternative of drying paddy.

The dryer was used to dry both long and short grain paddy (IR66 and IR70). Two drying sessions with grain mixing in between was maintained.

During the initial drying session from about 26-28%°C moisture content (wb) there was uneven drying, i.e., grains near the air inlet dried faster. However, during the subsequent drying session there was very little disparity in grain moisture content in the drying bin. Further, moisture contents monitored from different sacks at the end of the drying period were not significantly different.

The milling recovery of samples dryied were very close to the potential values. In contrast, there was slight reduction in head rice yield (at 5% significant level).

Table 1 Estimated Percent Losses in Paddy by Operations

Operations	Losses
1. Harvesting	1-3
2. Handling and transport	2-7
3. Threshing	2-6
4. Drying and cleaning	1-5
5. Storage	2-6
6. Parboiling and milling	2-8
Total	10-35 %

Background

For over three decades efforts have been directed at programs that seek to increase rice yields in developing countries in order to meet the demand of their growing populations. While field yield reflects the biological potential of the rice plant, it may not represent the quantity ultimately available for consumption.

Many international organizations and several individuals have published studies indicating the magnitude of losses in the post-production chain for rice. These losses can be summarized in **Table 1**.

While effors are being directed at higher yields, some attempts are also in the direction of reducing these losses with the aim of increasing the quantity of rice available to the consumer. It has been established that for rice post-production chain, mechanical systems incurred lesser physical losses and produced better quality milled rice than did the traditional methods (Toquero).

There is still a substantial gap between known technology and practice among the end users. This illustrates the magnitude of the problems currently facing rice post-harvest industry. There is a great need for appropriate equipment for cleaning, drying, handling, storage and milling.

The scope of the present study was limited to drying needs in the post production chain.

Drying of paddy on the pavements or highways which is prevalent among many rice farmers in developing countries cannot be considered as a substitute. Rather it is an indication of the problem. Studies have shown that such practice results in lowering milling recovery and head rice yield, let alone the traffic hazard inherent in this practice. The temperature of the sundrying floor surface and the grain may rise to as high as 60 to 70°C. This uncontrolled heating induces severe temperature and moisture gradient within the grain kernels resulting in a rapid drying rate and an induction of stress checks and cracks (Tumambing).

Although sundrying is undoubtedly a low-cost method, it is also labor intensive and subjects the grain to considerable quality deterioration, hence work on mechanical dryer suitable for the small farmers' group is felt wanting.

Design Criteria

In order to establish and confirm the drying needs of small-scale rice farmers (target group) a brief survey on paddy drying was conducted in Bicol and later, in Central Luzon regions of the Philippines. Farmers and rice millers were interviewed.

From the information gathered the following design criteria were outlined:

Target Groups (End Users)

The following were identified as the beneficiaries of the 4-ton dryer to be developed: farmer's cooperatives;farmers who live near rice mills; and small- and medium-sized rice millers.

Essential Features

1. To dry 1-4 tons of paddy per charge within 8 h;
2. Total cost of unit to be about $3 500;
3. Utilize rice hull as fuel;
4. Must have heat exchanger;
5. Easy to operate;
6. Should require only two persons to operate;
7. Easy to fabricate by small workshops;
8. Must require easy installation;
9. Should dry paddy evenly.

Undesirable Features

Based on the above criteria, a 4-ton capacity recirculating batch dryer was designed and fabricated. The unit consists of a hexagonal drying bin with a central cylindrical air distributor, holding or bagging bin, rice hull furnace with a heat exchanger and a blower assembly (**Fig. 1**). A bucket elevator was installed to facilitate grain loading and transfer to the holding bin. Except for the blower parts, plenum chamber, furnace, heat exchanger and the discharge valve, all parts of the unit were fabricated out of wood.

The heated air from the heat exchanger was forced across the grain bed by a blower through a perforated vertical plenum chamber at the center of the drying bin.

A counter flow fire tube heat exchanger was bolted on top of the rice hull-fired furnace. The temperature of the heated air going to the plenum chamber was varied by a bypass opening at the discharge end of the heat exchanger. The furnace used was a center tube type which was fed with rice hull fuel through its annular chamber. In order to control the rate of hull combustion, the inner grill of the furnace was rotated intermittently by a lever. The furnace was equipped with primary and secondary air supply pipes. The amount of air required for combustion was regulated by a butterfly valve.

Test Procedure

The dryer was tested at full load capacity with 4-5 tons per charge of wet paddy. The drying air at 43-45° was forced by a blower across the grain column through a central perforated plenum. Air pressure was maintained at 50 cm of water.

Fig. 1 4-ton recycling batch dryer.

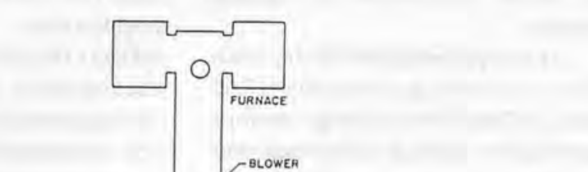

Fig. 2 Sampling locations.

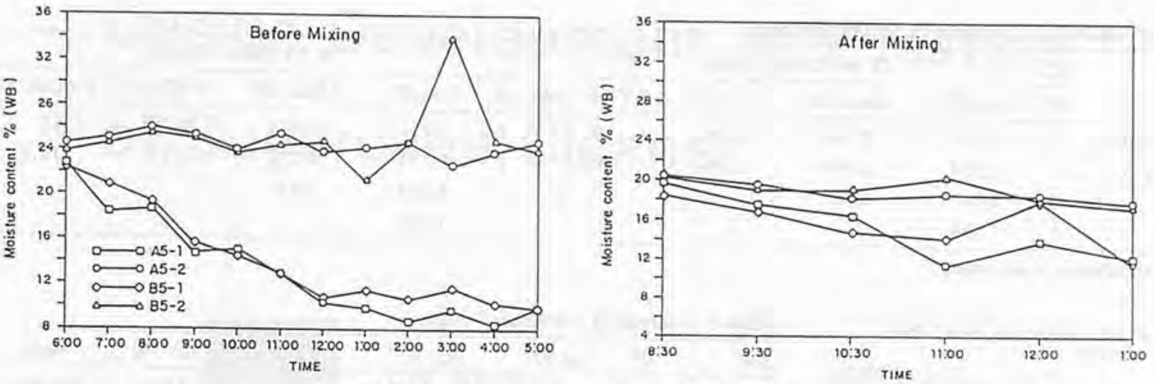

Fig. 3 Moisture content at section 5 for IR66.

For every hour, samples of paddy were withdrawn from 24 spots in the dryer bin for moisture determination (**Fig. 2**). Moisture content was determined instantly by a digital meter while portions of the samples were preserved for moisture content determination by even method. This was continued until a digital measurement at any section gave about 14% (wb).

Then the air flow was stopped and the grain was transferred by the bucket elevator into the holding bin. The grain was trasnferred back into the drying bin for further drying. This transfer of the paddy caused the grain to mix. The unloading and loading time took 25 min each.

The drying procedure was repeated this time with lower moisture content paddy. This was continued until the moisture content of the paddy at two or three sections registered 14% (wb).

At the end of the drying session the crop was transferred into the bagging bin. The resulting dried crop was allowed to cool then bagged for safe storage.

Samples of paddy were withdrawn at random from the sacks for final moisture content and milling quality determination.

The test was carried out for both long and short grain rice varieties.

Results and Discussions

Drying Rates

During the initial drying sessions grains in the inner core dried faster than those at the outer periphery (**Fig. 3**). Since the flow of the heated air was radially from the middle of the dryer bin to the outside, this phenomenon was expected. However, subsequent drying after mixing the crop resulted in very small grain moisture disparity. At most sectors the differences were negligible (**Fig. 3**). This clearly showed that mixing the crop between drying sessions was required in order to achieve even drying.

Moisture content of paddy monitored at random from sacks at the end of a drying period were not significantly different indicating that there were further moisture distribution within the grain (**Table 2**).

Both long and short grain rice varieties used (IR66 and IR70) exhibited similar drying characteristics as described above.

Milling Qualities

The milling quality of white rice is normally characterized by the following two parameters:

1. Milling recovery; percentage of milled rice from a given quantity of paddy rice; and
2. Head rice yield; percentage of whole* grains of total milled rice.

(*Any grain which is three-fourths of the kernel size or larger is termed as whole grain—Wimberly, 1983).

Usually the values of these parameters depend upon the history of the paddy. For instance, paddy crop which has been submerged in the field by flood or dried at high temperatures will have lower milling recovery and head rice yield. Over-drying followed by moisture absorption also has similar detrimental effects (Kunze).

The maximum values of milling recovery and head rice yield for a

Table 2 Moisture Content of Paddy at End of Drying Period

(Unit: %)

	IR 66	IR 66	IR 70	IR 70
	16.71	15.22	16.45	14.36
	16.60	15.43	15.03	13.01
	17.07	15.22	15.88	13.91
	17.34	15.44	18.75	12.90
	16.97	15.08		
	16.77	15.40		
Average	16.910	15.298	16.528	13.545
Standard deviation	0.248	0.134	1.379	0.612

* Sampled at random from sack.

Table 3 Analysis of Variance in Milling Recovery

Item	IR 66 (Long Grain)					IR 70 (Short Grain)				
	DF	Sum SQ	Mean SQ	F (Calc.)	F (Tab. 5%)	DF	Sum SQ	Mean SQ	F (Calc.)	F (Tab. 8%)
Replications	2	0.245	0.123	0.042	19	2	1.71	0.855	0.287	19
Factor A	1	2.804	2.804	0.96	18.51	1	0.171	0.171	0.57	18.51
Error	2	5.84	2.92			1	5.955	2.978		
Total	5	8.889				5	7.836			

* Not significant in all cases.

Table 4 Test Values of Head Rice Yield

Unit: %

Item	IR66	IR70
Shade drying	93.4	87.1
	92.6	87.7
	52.0	85.4
Average	92.7	86.7
Use of experimenteal dryer	79.8	82.4
	81.8	81.7
	83.6	81.1
Average	81.6	81.7

given crop are attained when the paddy is dried slowly with low temperature (less than 5°C above ambient) air. In many circumstances these values are regarded as the optimum for that particular sample.

For both long and short grain varieties used, the milling recovery obtained ranged between 68.7% and 78%. For each test there was no significant difference between milling recovery of samples dried in the shade or in the dryer (**Table 3**). This indicates that the dryer did not have any adverse effect on the paddy in terms of milling recovery.

Table 4 shows typical values of head rice yield determined for IR66 and IR70. In general, head rice yield values for samples from the dryer was lower than those for shade dried samples. There were significant differences between the set of values at 5% level (**Tables 5and 6**). This implies that the dryer, like other similar units, has a tendency of reducing the head rice yield of paddy.

Table 5 Analysis of Variance, Percent

Item	DF	Sum SQ	Mean SQ	F (Calc.)	F (Tab. 5%)	Signif.
Replications	2	2.123	1.062	0.259	0.19	Not sign.
Factor A	1	184.813	184.813	45.14	18.51	Sign. 5%
Error	2	8.188	4.094	—	—	—
Total	5	195.124				

	Means	LSD 5%*	LSD 1%*
Trial mean	87.11699		
Factor A		7.056	15.718
....			
Shade drying	92.667	A	A
Mechanical drying	81.567	B	A

* Factors with the same letter are not significantly different.

Table 6 Analysis of Variance, Percent

Item	DF	Sum SQ	Mean SQ	F (Calc.)	F (Tab. 5%)	Signif.
Replications	2	2.901	1.451	3.679	0.19	Not sign.
Factor A	1	37.502	37.502	95.113	18.51	Sign. 5%
Error	2	0.789	0.394	—	—	—
Total	5	41.192				

	Means	LSD 5%*	LSD 1%*
Trial mean	87.233		
Factor A		2.189	4.876
....			
Shade drying	86.733	A	A
Mechanical drying	81.733	B	A

* Factors with the same letters are not significantly different.

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Design Development and Testing of Sugarcane Cleaner

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Abstract

A snapping, roll-type sugarcane cleaner was designed, developed and tested. It separates the top from the cane by breaking it from mature cane and removing the green and dry leaves. The cleaner consists of feeding chute, cylinder, lower roller, side roller, flap roller, blower and an inclined platform fitted on a rigid frame. It is operated by 5.9 kW diesel engine and can be transported on three point-hitch of the tractor. The machine was tested on different varieties at different cylinder speeds and feeding chute angle. The trash left on the cane after passing through the machine vaired from 0.87 to 6.38%. The optimum feeding chute angle and cylinder rpm were 25° and 300 rpm, respectively. The machine output with single cane feeding varied from 3.8 to 8.23 q/h.

Introduction

Sugarcane is an important cash crop of Asia, Africa and South America. It is also grown in Australia, United States of America and some other countries of the world. Sugarcane harvesting is one of the most time- and labour-consuming, arduous operation. Harvesting includes base-cutting of the cane, cleaning, detopping, unloading and loading in the cart. To overcome the labour shortage, and reduce the cost of harvesting, sugarcane combines and harvesters have been developed. These machines are already in wide use in Australia, U.S.A. Brazil, Cuba and South Africa. However, these machines cannot be adopted in most of the developing countries at this stage due to different agronomic, economic, social and technical conditions. Sugarcane combines are designed for about 150 cm row-to-row spacing, their purchase price is very high, they are likely to displace labour and require higher degree of technical competence for their operation and maintenance. Transporting and processing of combine-harvested cane has to be done in about 16 h to beat the onset of deterioration. This will need a higher degree of managerial skill at the mill. Due to these reasons the exisiting sugarcane combines and harvesters cannot be adopted on a lare scale in most of the developing countries. However, sugarcane growers in these countries are facing labour shortage during harvesting period and some machine is needed to overcome this problem.

In India, sugarcane harvesting is done completely by manual labour. A field study conducted in the state of Punjab reveals that the labour requirement for manual cutting and cleaning (removing tops, dry and green leaves) of sugarcane required 157 man-h/ha and 395 man-h/ha, respectively. Since about 70% of the labour is required for cleaning the cane, it was considered prudent to develop a sugarcane cleaner for reducing total labour requirement.

Roberts (1972) reported whole stalk cane cleaning using hexagonal rolls. A corrugated metal sheet was placed flat in the cleaning bed between the 4 sets of hexagonal rools. Expanded sheet metal removed more than 80% of the trash and the corrugated metal removed 70% of trash. Kojima et al (1982) reported the mechanism of abrasion occuring on the surface of the rolls. They concluded that rough knurling was better than fine and higher pressure on rolls caused larger abrasion. Abrasion of roll surface increased due to the doping effect of sugarcane juice even on soft-nitrated roll surface.

Kojima et al (1986) reported the characteristics of leaf stripping upon the maximum dynamic pulling force. Pulling force of the knurling roll with knurls set on the surface of the roll was found to be larger than that of smooth rollers with smooth surface.

A prototype of sugarcane cleaner was designed and developed at the Department of Farm Power and Machinery, Punjab Agricultural University, Ludhiana. The paper describes the details of the cleaner at the test results.

Material and Methods

After reviewing the literature and considering the specific requirements of the sugarcane growers in developing countries, it was decided that:

1. The sugarcane cleaner should be of snapping roll type;
2. The machine should be powered with a 3.75 kW electric motor or 5.9 kW diesel engine:

Fig. 1 The sugarcane cleaner.

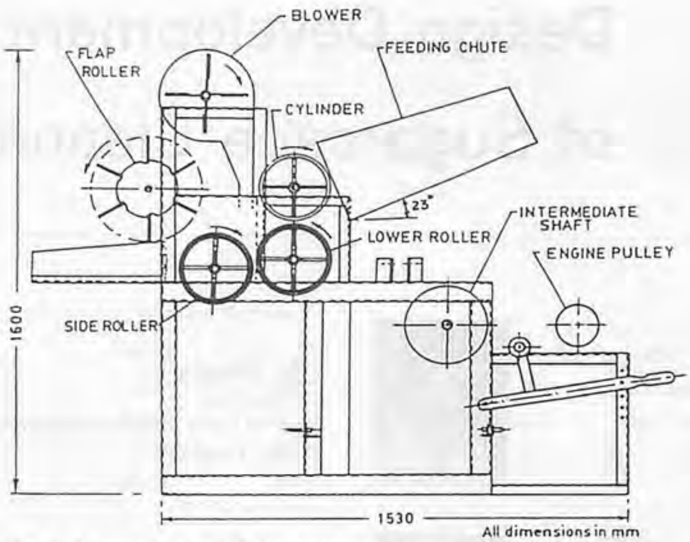

Fig. 2 Schematic view of the sugarcane cleaner.

3. It should be light, easily transportable; and
4. The output should be about 1 t/h.

The sugarcane cleaner was designed to remove the tops, dry and grean leaves from the whole stalk of sugarcane when fed with tops first. The basic principle on which the snapping roll type sugarcane cleaner function is based on the natural weak point at the joint of immature top with mature cane stalks. The immature top easily breaks due to difference in strength of the rind joint towards the immature top of the sugarcane stalks. The cleaner developed (**Figs. 1and 2**) consisted of feeding chute, cushioned cylinder, lower and side rollers wrapped with knurled rubber belt, blower, flap roller and an inclined platform fitted on a rigid frame. The specifications of the machine are given in **Table 1**. The machine can be mounted on three-point linkage of the tractor for easy transport.

Table 1 Specifications of the Sugarcane Cleaner

Component	Detail
Feeding chute	
a) Length	950 mm
b) Width	
i) Rear end	570 mm
ii) Front end	300 mm
c) Angle with horizontal	25°
Cylinder	
a) Length	310 mm
b) Outer dia.	240 mm
c) No. of cover flats	12
d) Thickness of cushion	15 mm
Lower and side rollers	
a) Length	310 mm
b) Outer dia.	250 mm
c) No. of flats	12
d) Thickness of cushion	6 mm
Blower	
a) No. of blades	4
b) Outer dia.	330 mm
Flap roller	
a) Length	310 mm
b) No. of flap rows	6
c) No. of flaps per row	7-8 (alternate rows)
d) Flap length	90 mm
Overrall dimensions	
a) Length	2350 mm
b) Width	900 mm
c) Height	1640 mm

Machine Operation

The cane stalks in single, double or triple with their tops first are fed to the counter rotating cylinder and lower roller through the feeding chute. The cane stalks are pulled and rolled by these pairs of rolls for snapping the top and leaves. The green leaves and tops are directed into the pocket (formed by side and lower roller) by axial blower whose discharge end is above it. The side and lower roller pulls the green leaves and tops downward until the natural weak point at the sugarcane top gets snapped to detach the green leaves and immature tops. The detached tops and leaves falls on the inclined platform. The flap roller moves against the motion of the cane stalk to comb the detopped cane stalk. The clean cane stalk falls away from the machine on the ground.

Test Procedure

Initially, the sugarcane cleaner was operated with a 3.75 kW variable speed patrol engine. It was observed that this power was insufficient for the machine operation. To overcome this problem, an 5.9 kW variable speed diesel engine was used and found acceptable. The tests were conducted to determine the effect of speed, feed chute angle and variety on machine performance. All tests were carried with single cane feeding. Varietal effect tests were conducted on 000-1148, 000-77 and 000-64, the three important cane varieties in Punjab. The feeding chute angles were 21, 25 and 28° while the cylinder speeds were 250, 300 and 350 rpm.

Each test was carried out with a sample size of 50 kg. The sugarcane stalk was fed with tops first. The feeding rate was single cane at a time. The time required for cleaning each sample was recorded. The material passing through the machine was separated and weighed manually into clean canes, tops and trash on the cane, tops and trash removed (i.e., falling on inclined platform) and tops and trash falling with the cane.

Results and Discussions

The effect of sugarcane variety, cylinder speed and feeding chute angle on extraneous matter removal from cane, cleaner output and cane breakage were analysed. The results follow:

Table 2 Effect of Variety and Cylinder Speed on Performance of Sugarcane Cleaner

Cylinder speed (rpm)	Extraneous matter: Remaining on cane (%)	Falling with clean cane (%)	Trash falling on inclined platform (%)	Trash automatically detached due to handling (%)	Total (%)	Broken (%)	Clean cane output (kg/h)
Variety 000-1148, Stalk length 365 mm, Clean cane length 235 mm, Cane dia. 1.5 cm							
250	1.57	1.60	16.7	2.8	22.67	0	380
300	1.20	2.00	16.2	2.7	22.25	0	408
350	1.04	2.04	17.0	2.5	22.58	0	528
Variety 000-77, Whole stalk length 360 cm, cane length 220 cm, cane dia. 1.7 cm							
250	1.72	2.10	15.0	5.0	23.82	0	415
300	1.21	2.40	15.8	3.65	23.06	0	492
350	0.87	2.50	16.2	4.72	24.29	2.0	555
Variety 000-64, Whole stalk length 350 cm, cane length 230 cm, cane dia. 1.7 cm							
250	4.75	22.5	17.0	2.4	27.5	0	400
300	4.50	2.75	18.0	2.3	26.4	0	480
350	3.69	2.80	16.8	2.3	27.39	2.3	504

Effect of Sugarcane Variety

The percentage of the extraneous matter on the cane before passing through the machine varied with the cane varieties. The extraneous matter removed from the cane by the cleaner is given in **Table 2.** The extraneous matter left on the cane after passing through the machine depended upon the variety and was higher in case of COJ-64 tna COJ-1148 and COJ-77. In all the cane varieties the dry leaves were almost completely removed but the green leaves were left on the cane near the top end. In the case of the COJ-64 cane variety it was observed that it was difficult to completely remove the green leaves even with hand and it required much more force than the other two varieties tested.

Cylinder Speed

The cylinder speed affected the percentage of the extraneous matter left the canes after passing through the machine (**Table 2**). In the cylinder speed range, when its speed increased from 250 rpm to 350 rpm the percentage of foreign matter on the canes after passing through the machine decreased for all the cane varieties from 1.57 to 1.04, 1.72 to 0.87 and 4.75 to 3.69% for COJ-1148, COJ-77 and COJ-64, respectively. The increase in the removal of extraneous matter with an increase in speed may be due to the increased air flow rate, increased impact force of the flap and better gripping of tops, green and dry leaves, due to increased pocket formed by the lower and side rollers. It was observed that at the lowest speed of 250 rpm the movement of the cane in the machine was not uniform which may be due to the insufficient pushing force at this speed. The detached extraneous matter falling with the canes increased with an increase in cylinder speed for all the cane varieties due probable to high inertia gained by the material while passing through the machine.

Sugarcane Damage

The damage to sugarcane while passing through the machine was observed in the form of cane breakage. The cane breakage was greatly affected by the speed, cane shape and variety. The breakage was observed at 350 rpm cylinder speed for the COJ-77 and COJ-64 varieties.

Effect of Feeding Chute Angle

The effect of feeding chute angle on cleaning is given in **Table 3.** The highest cleaning efficiency was observed at feeding chute angle of 25°. The percentage of for-

Table 3 Effect of Feeding Chute Angle on Cleaner Performance (000-64)

Feed chute angle 0	Total trash %	Trash, left on cane cane wt. basis %	Cane incompletely detopped %	Through-put q/h	Clean cane output q/h
21	24.05	5.79	42.76	10.53	7.81
25	23.37	4.28	30.70	10.67	7.89
28	24.92	6.38	54.40	11.09	8.28

eign matter attached to the cane was 4.28 at an angle of 25°, 6.38% at an angle of 28°and 5.79% at an angle of 21° of feeding chute. The increase percentage of attached foreign matter was directly due to variation in the percentage of undertopped canes in the samples. At optimum angle setting the percentage of improperly detopped canes was 30.7 while at other setting it was 42.76 and 54.40%

Output

The machine output (q/h) varied with the crop conditions, cylinder speed, and skill of the persons feeding the canes (**Table 2** and 3). The clean cane output increased with an increase in speed for all the varieties. The machine output varied from 3.8 to 8.23 q/h with single cane feeding.

Labour Requirements

Two persons are required for smooth operation of the machine. About 240 man-h/ha are required for cleaning sugarcane with the machine (machine output 5 q/h and cane yield) of 600 q/h) which is less than the labour required by manual method (400 man-h/ha). In addition to reduction in labour requirements, the machine removes the human drudgery of cleaning sugarcane. The labour requirements per hectare will be further reduced substantially by feeding two canes at a time. The limited trials on machine has shown that it can handle two canes at a time without any problems.

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Manufacture of Agricultural Machinery in Chile

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Abstract

The objective of this study was to characterize the Chilean agricultural machinery industry as a contribution to achieving a balanced and coordinated growth of this economic sector.

Thirty-eight of the 40 manufacturers of agricultural equipment were thoroughly surveyed. The results show that there is large concentration in the Metropolitan Region (61%); the largest growth of this sector occurred between 1965 and 1987, when 58% of the manufacturers initiated their activities; the work force is characterized by high utilization of professional and technical personnel; only 1 of the 38 manufacturers was selling an important part of his products (31%) outside of Chile.

Introduction

Developing countries should not attempt to implement a long term agricultural mechanization program with imports of sophisticated, capital intensive, labor efficient mechanical power units and associated equipment. The adverse economic effect that the hard currency cost of imported technology has on an often precarious balance in many developing countries can be critical. Moreover, a potentially more serious aspect of the long-term importation of mechanization equipment is the establishment of the developing country in a dependent position for food—a basic and strategic national commodity (1, 3).

Of course, developing nations do not have to start by reinventing the wheel. Most of the design principles for agricultural equipment were discovered in the 19th century. A vast body of knowledge exists through publications, conferences and visits to build upon. This free technology is not being properly utilized. In developing countries the real problems is not the lack of technical personnel for developing a self reliant agricultural machinery manufacture program, but that the available manpower is not properly mobilized and not given the opportunity to do responsible work.

Agricultural equipment covers a very wide range of machines requiring different levels of technology. Hand tools, hand-operated machines and animal-drawn equipment can be manufactured in small artisan workshops in most developing countries; tractor-drawn implements, irrigation and crop protection machines need a technology that can be progressively developed; power equipment and combine harvesters need sophisticated designs and complex technology not available in developing countries (3).

In the initial stages developing nations adopt a policy of imports, local demonstrations and maintenance; then take up local assembly and manufacture of foreign designs. This is followed by progressively raising the indigenous content, and eventually by some research and design work within the country itself. This is a reverse progression form that adopted in industrialized countries, and is the direct cause of the lack of well suited equipment designs for the crop and conditions of the farmers in developing countries. It needs to be realized that the large multinational companies will generally not put in the effort and money necessary for development of simple, economical machines needed in developing countries, when the market is small and returns are still far away (1, 2, 3).

The objective of this paper was to characterize the Chilean agricultural machinery industry as a contribution to fostering its development and that of agriculture.

The Latin-American Machinery Industry

The 1st Regional Latin-American Meeting on the Agricultural Machinery Industry was carried out in Santiago, Chile from November 2nd to 6th, 1987 (5). Its objectives were:

1. To promote the development

Table 1 Regional Location of Machinery Manufacturers in Chile

Region	Manufacturers	
	Number	% of total
I	1	2.6
V	1	2.6
Metropolitan	23	60.5
VI	3	7.9
VII	3	7.9
VIII	1	2.6
IX	3	7.9
X	1	7.9
Total	38	100

Source: SERCOTEC (4).

Table 2 Years of Work Initiation

Region	Enterprise code	Name of enterprise	Year
IV	24	DALMI, Ltd.	1960
V	25	CIMA, Ltd.	1978
Metropolitan	1	AGRICOSAN, Ltd.	1983
Metropolitan	2	Pulverizadores Agr. PARADA	1947
Metropolitan	3	SOGECO, Inc.	1941
Metropolitan	4	INCOMAQ	1968
Metropolitan	5	ASSA Ingeniería	1976
Metropolitan	6	INFUMAG, Ltd.	1970
Metropolitan	7	Soc Electrometalúrgica GATTI	1980
Metropolitan	8	EDYCE, Inc.	1953
Metropolitan	9	BITTIG & BOILLAT	1925
Metropolitan	10	TECHNIAGRO, Inc.	1987
Metropolitan	11	Industria Mecánica VOGT, Inc.	1954
Metropolitan	12	GHC	1949
Metropolitan	13	SURCO	1986
Metropolitan	14	Metalúrgica Sudamericana, Inc.	1967
Metropolitan	15	Jaime Gamonal S.	1974
Metropolitan	16	Ramón Zambrano V.	1952
Metropolitan	17	ICAT, Ltd.	1959
Metropolitan	18	Amador Tapia Rivas	1958
Metropolitan	19	José Godoy e Hijos, Ltd.	1955
Metropolitan	20	Homberger and Co. Ltd.	1958
Metropolitan	21	Maestranza SEEMAN, Ltd.	1965
Metropolitan	22	Fabrizio Lévera P.	1979
Metropolitan	23	CARS, Ltd.	1967
VI	26	Lara H. Eugenio	n.i.
VI	27	PELECO	1951
VI	28	DALMAC, Ltd.	1984
VII	29	ARGOMETAL, Ltd.	1986
VII	30	Almenara and Co., Ltd.	1957
VII	31	Pulverizadores RIAL, Ltd.	1974
VIII	32	Maestranza F y F	1982
IX	33	Brever L. Reiner	1980
IX	34	MAYOV	1982
IX	35	Maestranza BOLOMEY	1983
X	36	Fundición IBERIA	n.i.
X	37	Schultze and Stimper	1923
X	38	Aerobombas Guillermo Mohr	1974

n.i. = no information; Source: SERCOTEC (4).

of the agricultural machinery industry, through the exchange and transfer of technology among the enterprises and experts;

2. To foster the industrialization process through the analysis of advanced designs, new models, new industrial initiatives, complementary industrial and investment agreements;
3. To obtain better levels of productivity through an analysis of the normalization of materials and machine parts, the supply of raw materials, training and technical assistance, financing, testing centers, and institutions of research and development;
4. To develop the manufacture of equipment needed to obtain appropriate mechanization levels that would enable the progress of the agricultural sector.

These objectives emphasized the need to establish the characteristics of the present, made in Chile, agricultural machinery supply, in order to foster the regional exchange and to facilitate and enhance the export flow of machines.

Methodology

A complete survey of 38 out of the 40 manufacturers of agricultural equipment in Chile, between the IV and X Reions, was carried out by the Technical Cooperation Service (SERCOTEC) which is a government agency (4).

The modal value for the frequency of enterprise activity initiation was calculated with the following equation:

$$Mo = L + i \frac{d}{d_1 - d_2}$$

where,

No = modal value;

L = lower limit of class modal;

i = amplitude of class modal and that of the two classes immediately adjacent;

d_1 = difference between the frequency of the class modal and that of the immediately below;

d_2 = difference between the frequency of the class modal and that of the class immediately above.

Industry Characterization

Location

Table 1 shows the regional distribution of agricultural equipment manufacturers in Chile. It can be seen that they are concentrated in the Metropolitan Region (60.5%), of which 35% are located in the capital city of Santiago.

Age

Table 2 shows the year work was initiated at the different enterprises. **Table 3** groups the years in a distribution with a general amplitude of 15 years, approximately. It can be seen that the largest growth of this industrial sector occurred between 1965 and 1987, when 58.4% of the manufacturers initiated their activities. The modal value is located between 1965 and 1979, especifically the year 1974.

These estimators indicate that this sector has had a recent growth that is closely related to the development of the agricultural sector.

Table 3 Frequency of Year of Work Initiation, 1923-1987

Year	Number of manufacturers	%
1923-1934	2	5.5
1935-1949	4	11.1
1950-1964	9	25.0
1965-1979	11	30.6
1980-1987	10	27.8
Total	36	100

Personnel

Table 4 presents the amount and type of workers employed by the agricultural equipment manufacturers. The work force is characterized by the high utilization of professional and technical personnel. It can be seen that the weighted average of the relation technical personnel/total personnel is 9%, which goes up to 38.8% if the qualified workers are included in the technical personnel. These estimators give this industrial sector a reasonably high technical level.

Table 4 Labor Employment by the Machinery Industry

Code	Total Personnel	Professionals and technic.	%	Work force			
				Total	Non qualified	Qualified	%
1	40	2	5.0	38	26	12	31.6
2	100	5	5.0	95	75	20	21.1
3	97	10	10.3	87	34	53	60.9
4	68	3	4.4	65	55	10	15.4
5	60	6	10.0	54	34	20	37.0
6	18	1	5.6	17	9	8	45.1
7	40	3	7.5	37	15	22	59.5
8	40	5	12.5	35	30	5	14.3
9	60	6	10.0	54	39	15	27.8
10	17	2	11.8	15	11	4	26.7
11	65	5	7.7	60	45	15	25.0
12	35	5	14.3	30	16	14	46.7
13	8	2	25.0	6	3	3	50.0
14	28	4	14.3	24	6	18	75.0
15	21	3	14.3	18	15	3	16.7
16	14	0	0.0	14	13	1	7.1
17	17	3	17.6	14	9	5	35.7
18	21	0	0.0	21	17	4	19.0
19	20	0	0.0	20	16	4	20.0
20	80	6	7.5	74	54	20	27.0
21	35	2	5.7	33	29	4	12.1
22	68	7	10.3	61	53	8	13.1
23	90	10	11.1	80	10	70	87.5
24	5	2	40.0	3	0	3	100.0
25	34	6	17.6	28	8	20	71.4
26	25	0	0.0	25	24	1	4.1
27	14	2	14.3	12	7	5	41.7
28	42	3	7.1	39	17	20	51.3
29	19	4	21.1	15	11	4	26.7
30	23	5	21.7	18	5	13	72.2
31	45	3	6.7	42	25	17	40.5
32	16	5	31.3	11	0	11	100.0
33	29	1	3.4	28	16	12	42.9
34	14	1	7.1	13	9	4	30.8
35	22	2	9.1	20	7	13	65.0
36	8	0	0.0	8	6	2	25.0
37	12	0	0.0	12	6	6	50.0
38	35	1	2.9	34	14	20	58.0
Total	1385	125	9.0	1260	771	489	38.8

Source: SERCOTEC (4).

Area Occupied

Table 5 presents the area occupied by the different machinery manufacturers in Chile.

Table 5 Area Occupied by the Machinery Industry (m^2)

Enterprise code	Land	Buildings	Enterprise code	Land	Building
1	1,000	700	20	4,000	3,000
2	3,156	2,864	21	13,900	2,100
3	16,000	5,040	22	5,000	1,174
4	1,600	1,200	23	18,541	3,655
5	8,000	5,000	24	5,000	1,200
6	1,120	325	25	4,100	1,200
7	600	500	26	2,400	630
8	—	2,000	27	20,000	1,100
9	2,500	2,500	28	5,500	1,600
10	600	200	29	400	350
11	3,500	3,500	30	3,300	100
12	1,260	1,200	31	3,000	2,000
13	2,200	789	32	1,000	550
14	11,500	2,000	33	1,840	1,238
15	5,600	600	34	300	250
16	600	650	35	5,000	950
17	1,500	1,200	36	1,100	700
18	1,200	1,200	37	1,600	1,000
19	2,100	1,500	38	1,600	1,200

Source: SERCOTEC (4).

Installed Capacity

The present supply of agricultural equipment manufactured in Chile is presented in **Table 6**. The table shows a large variety of machines offered to the farmers and the large number of manufacturers for a country with less than 2 million hectares cultivated land yearly.

Sales Destination

Of the 38 manufactures that were analyzed in this study, only 5 were exporting their products of which only one was selling an important part of his products (31%) outside of Chile.

However, a large majority of machine manufacturers stated their willingness and capacity to sell abroad, as it can be seen in

Table 6 Agricultural Equipment Manufactured in Chile

Implements	Number of manufacturers	Implements	Number of manufacturers
Tillage	43	Harvesters	9
One-way disk plows	1	Potato	4
Reversible disk plows	1	Rice	1
Chisel plows	10	Forage	3
Subsoilers, 1-3 shanks	5	Sugar beet	1
Vibrocultivators with clod buster rollers	4	Transport	36
Disk harrows, 14-22 disks	9	4-wheel wagons, with turntable	7
Spike-tooth harrows	3	4-wheel wagons, without springs	1
Ridgers (listers)	5	4-wheel wagons, fruit harvesters	11
Furrowers	5	4-wheel wagons, bin carriers	9
Earth-moving machines	5	2-wheel wagons, articulated	2
Micro leveller blades	2	Special wagons	3
Scrapers	2	Front loaders	1
Ox-drawn blades, articulated	1	Tractor-mounted loaders	2
Seeding-fertilization	6	Other equipment	28
Grain drills	1	Mills, grinders	6
Potato planters	3	Pumps	8
Centrifugal fertilizer distributors	1	Silos	1
Orchard fertilizer distributors	1	Materials handling	4
Cultivation-plague control	19	Irrigation	3
Tool carriers	2	Fans	1
Field sprayers	5	Dryers	1
Blower sprayers	5	Feeding plants	2
Dusters-sulfur applicators	4	Packing lines	2
Rotary cutters	3		
Grapevine cutters	2		

Source: Kunze (2); SERCOTEC (4).

Table 7 Export Capacity of Machinery Manufacturers

Enterprise code	Item	Units/year	Enterprise code	Item	Units/year
3	Wagons	1,500	25	Soil movers	12
6	Sprayers	75,000	25	Residue processors	36
7	Horticultural machinery	20	25	Cutter	24
9	Grinders	100	25	Harvesting wagons	180
10	Sulfur applicators	200	25	Self unloading wagons	24
11	Pumps	—	29	Harvesters	—
13	Tillage equipment, sprayers, wagons	—	30	Packing lines	2
14	Disks for plows	207ton	31	Packing lines	5
17	Tillage equip., seeders, sprayers	—	31	Sprayers	80
18	Pumps	—	32	Chisel plows	50
20	Wagons, feed plants	—	32	Tooth and roller harrows	200
21	Wagons, silos, augers, chains grinders, dryers	—	32	Vibrocultivators	80
24	Potato planters	120	33	Animal traction harrows	500
24	Potato harvesters	720	33	Hammer mills	120
24	Ridgers	240	33	Grain cleaners	50
24	Furrowers	240	33	Forage harvesters	500
24	Harrows	120	33	Weed cutters	30
25	Plows	108	33	Rollers	150
25	Field cultivators	60	34	Slurry distributors	10
25	Subsoilers	36	35	Grain deposits	50
25	Levelers	24			

Table 7. Export capacity was defined as the group of products that could be exported, given their quality and price, after supplying the internal market.

Conclusions

There is a large concentration of manufacturers (61%) in the Metropolitan Region. The largest growth of this industrial sector occurred between 1965 and 1987 when 58% of the manufacturers initiated activities; these indicators show that the growth of this sector is relatively recent.

One of the main characteristics of the enterprises is the employment of a large number of professionals and technicians; the weighted average of the relation technical personnel/total personnel is 9%, which goes up to 39% when the qualified workers are included in the technical personnel.

Only 5 manufacturers (13%) were exporting their products in small quantities, with one exception in which 31% of the production is sold outside of Chile. However, 68% of the manufacturers stated their interest in the export market.

A large number of the surveyed manufacturers (81%) said they had development projects for new machines, and 71% of the manufacturers indicated their need of loans for equipment, buildings and operational capital.

(Continued on page 66)

Agricultural Inputs, Mechanization and Employment in Turkey

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Abstract

Agricultural mechanization has not a direct effect in increasing farm yield. But it helps to use modern technologies in agriculture such as fertilizer spreading, irrigation, pesticide, etc. It eases working conditions in the rural area and provides manpower to other sectors.

According to 1988 statistics, Turkey has 650 000 tractors and its mechanization level was 1.0 kW/ha. The use of fertilizer is about 8 million ton and pesticide use is 60-70 thousand tons. Irrigated area reached about 3 million hectare. When the Southern Anatolia Project is completed, a total of 5 million hectares of land will be available.

Mechanization level in field crops reached its maximum but in animal husbandry and horticultural production, its level is still not so high. The use of electrical energy in rural areas is limited only to lighting and electric devices.

The automotive industry manufactured 181 014 different kinds of vehicles in 1988 of which 17.3% were farm tractors.

Direct employment in the automotive industry employed 25 thousand persons of which 6 631 worked in tractor manufacturing area. Directly and indirectly, this sector create 140 000 posts in Turkey's total employment.

The number of companies that produce farm implements were 846 in 1988. Seventeen of them had an employment capacity more than 100 persons. The others have the character of small workshops. The total different kinds of implements manufactured in 1988 amounted to 150 thousand units.

According to the norm, one post in tractor manufacturing industry creates 20 new posts and one post in farm implement production creates 10 new posts. The total employment capacity in tractor and manufacturing industry (including repair shops, dealers, etc.) are about 260 000 persons.

Turkey's economically active population is 20 million. This means that tractor and farm implement manufacturing employment capacity is 1% in total employment in Turkey.

Introduction

Increasing agricultural productivity depends on the use of some inputs or technologies such as developing soil and water sources, irrigation fertilizer application, spraying, quality seed, and mechanization. These inputs directly or indirectly affect the yield of crops.

Among the agricultural inputs, farm machineries represent the biggest energy input in the developed countries. The second is fertilizer (Gifford, 1986: Tezer and Sabanci, 1987; Isik, 1988).

In 1963, the planned development period started in Turkey. The agricultural sector has since been developing step by step, especially in the mechanization applications. The first agricultural implement was manufactured during the planned period (Anonymous, 1987).

In this paper, the increase in agricultural production and introduction of farm mechanization, relationships between mechanization industry and employment is investigated.

Agricultural Structure

Agriculture in Turkey generally depends on field crops and animal production. The distribution of agricultural area in Turkey and its development is given in **Fig. 1**.

As shown in **Fig. 1**, the total agricultural area is about 27 millions hectare, and it has not greatly changed since 1963. Approximately, 90% of the total agricultural

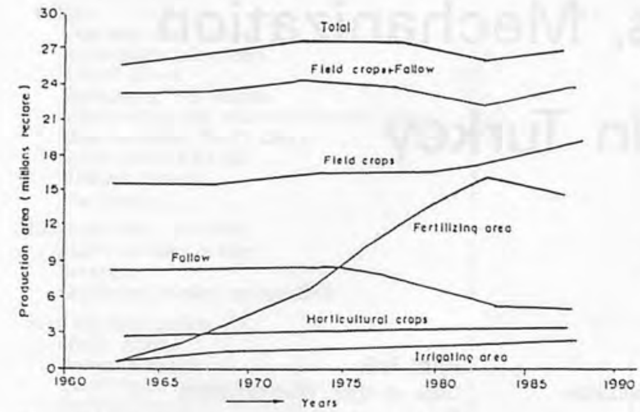

Fig. 1 Distribution of agricultural area in Turkey.

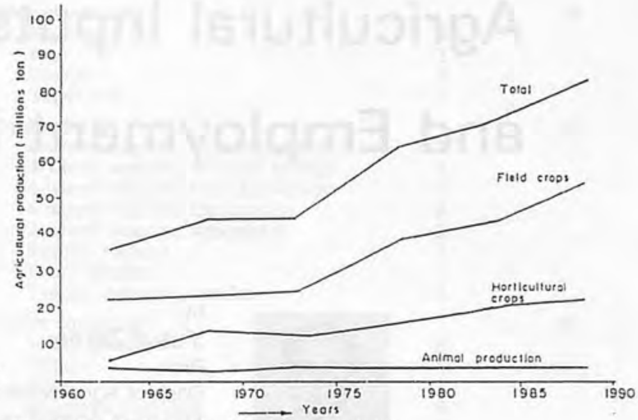

Fig. 2 Trend in agricultural productivity.

Fig. 3 Trend in fertilizer use.

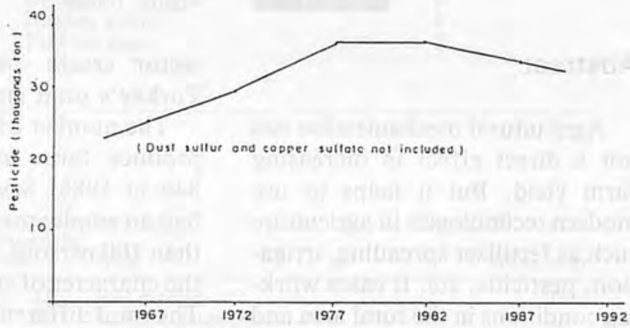

Fig. 4 Trend in pesticide use.

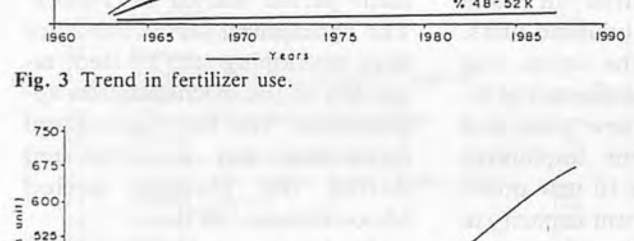

Fig. 5 Increase in tractor number. (Average tractor life: 12 years)

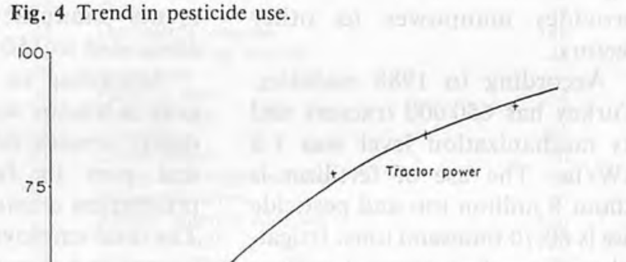

Fig. 6 Distribution of source of farm power.

area is planted to field crops and 10% to horticultural crops. The fallow area has been decreasing in size, especially since 1980. On the other hand, the agricultural area where the use of fertilizer and irrigation facilities have been introduced tended to increase over time.

As shown in **Fig. 2**, the agricultural production has been increasing, and it has been predicted that production will reach approximately 90 million ton in 1990. Much of the produciton is in field crops and animal produciton is quite low.

Fig. 3 indicates the trend in the use of fertilizer which peaked in 1980 but has since been declining. The use of pesticides in **Fig. 3** increased between 1967 and 1980 but also tended to decline since. **Fig. 5** shows a constant increase in

Table 1 Distribution of Sources of Farm Power

Year	Manual Power (%)	Animal Power (%)	Tractor Power (%)	Electrical Power (%)
1960	22.13	41.85	35.83	0.19
1965	19.38	37.38	42.99	0.25
1970	15.27	23.20	61.12	0.31
1975	7.68	10.69	81.39	0.24
1980	4.81	6.86	87.83	0.50
1985	4.30	3.53	91.25	0.92
1987	4.43	3.00	91.35	1.22

the number of tractors in use in the country.

Table 1 and **Fig. 6** shows in graphic presentation the trend in the source of farm power in Turkey. Manual and animals were the major sources of power until 1970 when tractor power started to become popular. Between 1975 and 1987 manual and animal power sources declined to a very low level in contrast to farm tractors which were supplying over 90% of the total farm power. Electrical power as a source of energy has yet to make a headway.

Relationship Between Employment and Farm Mechanization

The agricultural mechanization aspect in Turkey has been increasing since 1960. The use of tractor power increased from24.3 kW/ha in 1960 to 38.1 kW in 1984. In terms of farm mechanization level, this has increased from 0.04 kW/ha in 1960 to 0.97 kW/ha in 1984 (**Table 2**). This is graphically illustrated in **Fig. 7**. The rural population ratio has been decreasing because of the increase in mechanization level.

Table 2 Changes in Tractor Used Mechanization Level

Years	Average tractor power	Mechanization Level (kW/ha)
1960	24.3	0.04
1965	25.9	0.05
1970	27.4	0.10
1975	28.3	0.27
1980	36.3	0.59
1985	37.7	0.96
1986	38.1	0.97

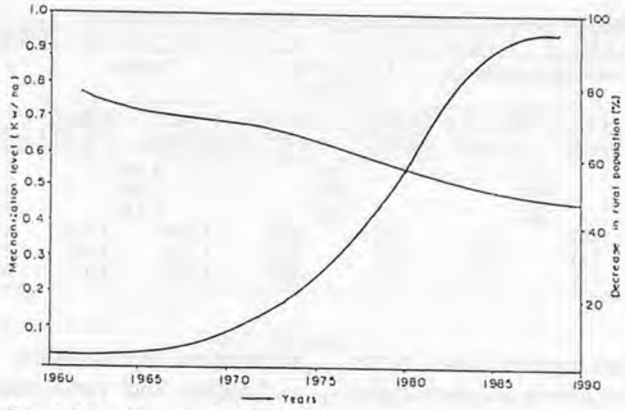

Fig. 7 Change in mechanical level.

Table 3 Tractor Manufacture

Company	Capacity in 1987	Production in 1987	Use of capacity (%)	Employment Unit = person
CUMITAS*-MERSIN (Deere and Company)	10 000	113	1.1	351
HEMA-KAYSERI (Ford)	10 000	12	0.1	349
ILTOR-ISTANBUL (Nibbi-Goldini)	3 600	531	14.8	57
T.O.E.-GEBZE (I.H and CASE)	12 000	—	0.0	563
TZDK-ADAPAZARI (Steyr)	15 000	4 773	31.8	1 554
UZEL-ISTANBUL (Massey Ferguson)	30 000	18 564	61.9	1 908
TÜMOSAN-KONYA (Fiat)	30 000	112	0.4	700
T.TRAKTÖR-ANKARA (Fiat)	22 500	12 002	53.3	1 111
	133 100	36 107	—	6 593

* CUMITAS is the only combine manufacturer and its capacity utilization in 1986 was 7% (Capacity was 1 200, production was 84).

Table 4 Tractor Supply in Turkey

Years	Domestic manufacture in Turkey	Import	Export	Share of home made parts in manufacturing (%)	Use of capacity (%)
1963	8 135	—	—	25.0	—
1968	15 281	—	—	50.0	—
1970	7 921	412	—	50.0	—
1973	32 484	4 922	—	55.0	—
1975	32 691	19 468	—	57.5	49.9
1978	18 202	14 311	—	67.5	21.3
1980	17 179	3 692	92	70.0	17.5
1983	41 799	28	7 008	75.0	34.3
1985	37 903	552	3 679	75.0	24.3
1987	36 107	347	73	85.0	23.9

At the present time, there are 8 companies that manufacture tractors in Turkey. The total production capacity of these companies is about 133 000, but the total production was only 36 107 units in 1987 or a capacity utilization of about 27%.

Table 3 shows the list of tractor manufacturers in the country with the corresponding capacity and produciton in 1987, use of capacity and employment figures. The share of home made parts in the manufacture of tractor is about 85%. Import and export rates are very low. Majority of the workers in the tractor manufacturing companies are skilled workers (60.5% in 1988).

Table 4 compares the magnitude of locally made tractors;

Table 5 Characteristics of Persons Employed in Tractor Manufacture

(Unit: person)

Year	University graduate		High school graduate		Worker		Total
	Technical staff	Managerial staff	Technical staff	Clerical staff	Not skilled	Skilled	
1978	124		681		4 368		5 173
1980	228		1 098		6 265		7 592
1982	268		1 248		6 872		8 388
1984	177	135	240	524	1 390	3 724	6 190
1986	143	112	242	521	1 181	3 680	5 880
1988	158	132	287	478	1 561	4 015	6 631

imports and exports; share in the local manufacture of spare parts and capacity use.

The characteristics of persons employed in tractor manufacture in Turkey are given in **Table 5**. As might be expected, the technical and managerial staff are college graduates even as high school graduates are also qualified as technical staff.

Conclusion

Agricultural produciton in Turkey, especially after the planned period (since 1963) has greatly increased. Tractors and agricultural machinery that affected production increase have an important role among the production technologies.

Tractor and farm machinery manufacturing sectors have an important place in employment. Majority of employees are workers. In the near future, it will be very important to increase the number of technical personnel in order to improve tractor manufacture.

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Farm Mechanization vis-a-vis Human Labour Employment in Punjab Agriculture

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Abstract

Seed-irrigation-fertilizer technology has proved to be labour augmenting whereas the impact of farm mechanization on human labour employment continues to be a debatable issue. Some hold the view that it displaces human labour when farm operations are mechanized while other say that it increases human labour use by increasing cropping intensity, bringing labour intensive shifts in cropping pattern and increasing the level of productivity of the farms. This paper is concerned primarily with this issue and shows that tractorization did not replace human labour. There was no significant difference in human labour use on tractor-operated farms and bullock-operated farms. The introduction of harvesting combines, however, significantly reduced the use of human labour on the farms. Therefore, the process of its further expansion should be properly monitored and controlled in the coming years in order to avoid social costs of labour displacement. On the other hand, tractorization became an important compoment of new production technologies in Punjab agriculture, more out of technical necessity to increase agricultural production, rather than to substitute human labour on western agricultural model. It is estimated that the demand for human labour would grow to the tune of 8% by 1995-96 if mechanization continues its presnet pace.

Introduction

In the most of the developing countries like India, agricultural policy has aimed at increasing productivity through the adoption of modern technologies. These include introduction of high yielding varieties, assured irrigation, greater use of non-conventional inputs like fertilizers, pesticides, weedicides, etc. and farm mechanization. Since the evolution of the Mexican high-yielding wheat varieties in the mid-sixties, Pumjab agriculture has experienced a very rapid technological change. Almost all the area has come under seeds of high yielding varieties which are very responsive to irrigation and fertilizers. About 85% of the total cultivated area of the state has come under assured irrigation and per hectare fertilizer consumption has increased from 15.5 kg in 1970-71 to 61.2 kg in 1985-86. This combination of seed-irrigation-fertilizer technology also placed premium on timeliness and precision of farm operations which paved the way for farm mechanization, especially tractorization. The strong need for tractorization was also felt due to the adoption of multiple cropping system. As a result, the number of tractors in the state has gone up from 41 000 in 1970-71 to 230 000 in 1985-86.

Seed-irrigation-fertilizer technology augments land and labour resources whereas the impact of traetorization remains inconclusive and continues to be a debatable issue. Some hold the view that tractorization enhances farm productivity as well as human labour absorption capacity while other say that it, no doubt, augments the land productivity but displaces human labour. It is generally agreed that up to the present time, the whole package of new technologies has increased the demand for human labour. But it is feared that this trend is not likely to continue, keeping in view the introduction of harvesting combines and other labour-saving innovations. The present study purports to examine this issue in perspective by:

i. examining the human labour employment pattern at different levels of mechanization;
ii. projecting the demand for human labour in Punjab Agriculture, and
iii. discussing some broad employment implications of farm mechanization.

Methodology

The study was based on the data collected from the "Comprehensive Scheme to Study the Cost of Cultivation of Principal Crop in Punjab" for the agricultural year 1981-82. In this scheme, Punjab state was divided into three homogeneous zones, namely: (i) wheat-paddy-maize zone; (ii) wheat-maize-groundnut zone; and (iii) wheat-cotton-bajra zone on the basis of similarity in cropping pattern, soil type, irrigation, rainfall and productivity. By using three-stage stratified random sampling technique, 20 "tehsils" (cluster of village units) were selected as first-stage sampling units (9 from zone I, 5 from zone II and 6 from zone III with probability proportional to the area under principal crops of that zone to the total area under principal crops in the state). Then one cluster containing three villages for each tehsil with varying probability was selected at second stage sampling unit and 10 operational holdings, two for each of the five-sized groups based on cumulative frequency method, from each cluster were selected at third-stage sampling unit of the study. In this way, 200 operational holdings were selected for the whole state. Since our objective was to examine labour use pattern at different levels of mechanization, these holdings were classified into bullock-operated farms (BOF); tractor operated farms (TOF); and tractor operated plus combine harvester using farms (T+CHr) on the basis of main source of draft power on these farms. Thus a sample of 95 bullock-operated farms, 85 tractor-operated farms and 25 tractor-operated plus combine harvester using farms was formed for this purpose. The average farm size of these categories was 4.65, 9.07 and 10.99 ha, respectively. Data were collected on labour use, other inputs' use, levels of production, etc., for all the crops and for the farm as a whole. Tabular analysis was done to examine the labour employment pattern on different farm categories. Differences in labour use among various farm categories were investigated in relation to changes in cropping pattern, cropping intensity, inputs use and level of output.

Human Labour Use Pattern at Different Levels of Mechanization

Table 1 depicts the use of human labour and other inputs, level of output and cropping pattern at different farm categories. It was noticed that there was no significant difference in labour use between TOFs and BOFs. The former farms employed a little more labour to the tune of 15 h per hectare as compared to the latter farms. In spite of a higher use of tractors and weedicides, increase in cropping intensity, larger proportion of area under labour intensive crops like paddy, potato and sugarcane, increased use of fertilizers and higher level of production resulted in more hu-

Table 1 Per Hectare Use of Human Labour and Other Inputs, Level of Output and Proportion of Area undere Different Crops on Different Categories of Farms, 1981-82

Item	BOFs	TOFs	T+CHrs
Family labour (h)	672.87 (61.22)	419.92 (37.69)	340.48 (34.63)
Permanent+casual labour (h)	426.30 (38.78)	694.08 (62.31)	642.65 (65.37)
Total labour (h)	1099.17 (100.00)	1114.00 (100.00)	983.13 (100.00)
Bullock labour (h)	80.48	37.64	12.81
Tractor use (h)	2.65	27.74	31.02
Feartilizer+manures (Rs*)	984.57	1232.71	1621.80
Pesticides (Rs)	39.86	42.66	59.91
Weedicides (Rs)	29.92	59.68	137.18
Irrigation (h)	199.95	213.55	266.22
Gross output (Rs)	7487.59	8481.47	9907.33
Area under major crops (%)			
Paddy	13.79	17.14	29.28
Cotton	15.25	9.33	6.20
Maize	4.34	5.21	2.28
Sugarcane	2.88	4.16	2.61
Wheat	36.97	39.75	43.95
Gram	3.45	1.26	0.80
Potato	1.05	3.46	0.79
Cropping intensity	174.51	180.22	187.07

BOF stands for Bullock Operated Farms, TOF for Tractor Operated Farms and T+CHr for Tractor Operated+Combine Harvester Using Farms.
*One US$ was equal to Rs 9.38 on April 2, 1982.
Figures in parentheses indicate the percentage to the total labour use.

Table 2 Per Hectare Human Labour Requirements for Different Crops on Different Categories of Farms in Punjab, 1981-82 (Man-days)

Crop	Bullock Farms BOFs	Tractors Farms	
		TOFs	T+CHrs
Paddy	129.01	105.17	77.69
Wheat	56.71	48.80	18.96
Cotton (Am)	99.13	107.96	N.A.
Cotton (Desi)	140.79	116.16	N.A.
Maize	82.52	59.64	N.A.
Groundnut	78.88	74.38	N.A.
Sugarcane	145.65	184.27	N.A.
Gram	42.65	42.24	N.A.
Other pulses	43.75	38.59	N.A.
Barley	48.66	47.85	N.A.
Rapeseed and mustard	74.68	71.02	N.A.
Potato	157.78	129.90	N.A.
Fodder	77.85	67.78	N.A.
Other vegetables	171.44*	N.A.	N.A.

*This figure gives the labour requirements for all the farms taken together since area under vegetables for these categories separately was negligible.
Source: Human Labour requirements are estimated from the sample used for this study.

man labour use on TOFs as compared to bullock-operated farms. The displacement of human labour that took place due to substitution of bullocks' labour by tractors and higher use of weedicides on TOFs, was more than made up by labour employment increasing the effects of higher cropping intensity, labour intensive shift in cropping pattern, greater use of fertilizers and pesticides and high level of output.

A significant decrease in per hectare human labour use to the extent of 116 h (10.55%) and 131 h (11.75%) was, however, witnessed on T+CHrs as compared to BOFs and TOFs, respectively. In this category, about 30% of wheat and 62% of paddy crops was harvested and threshed by combine harvester which are highly labour saving devices. Besides, almost a total elimination of bullock labour input and intensive use of weedicides per hectare were other important factors responsible for bringing a sharp decline in human labour input on these farms. Further, these had higher proportion of area under paddy and wheat crops which were more prone to the labour substitution effects of tractorization and weedicides (**Tables 1** and **2**). Substitution effects of mechanization and weedicides here were so strong that even higher cropping intensity, higher use of inputs and higher level of output could not offset them.

Another interesting point emerging from **Table 1** is that the share of hired labour to the total human labour employed on the farms increased as the level of mechanization increased. Even in absolute terms, the magnitude of per hectare hired labour was higher at 694 hour and 642.65 hours, respectively, on TOFs and T+CHrs as compared BOFs where it was only 426.3 hours per hectare. This shows that mechanization did not reduce wage employment; rather it increased the same. This also means that farm mechanization replaced family labour only.

Demand Projections for Human Labour in 1995-96

Attempt is made in this section to project demand for human labour for the year 1995-96. It is argued that increased tractorization and introduction of harvesting combines in Pumjab agriculture is likely to cause a decline in the demand for human labour in the coming years. In the absence of employment avenues in other sectors of the economy and increase in the population, the problem of unemployment/disguised unemployment might become serious. This problem is more likely to be serious for landless agricultural labour force which has no other source of income.

The aim of this exercise is to give some broader directions as to what would be the extent of human labour absorption in crop production sector in Punjab agriculture in the future in the wake of increased mechanization and changes in crop-mix. In pursuit of this, the demand for human labour was projected for the year 1995-96 by using a physical projection model. This analysis is based on the following assumptions:

1. The gross cropped area of the state under tractors for the year 1981-82 was estimated by multiplying the average gross cropped area per tractor on the sample farms with the number of tractors (1.32 lakhs) in the state. In this way, the gross cropped area of the state was apportioned under bullock farms and tractor farms as 4639460 and 2289540 hectares, respectively.

2. Cropping pattern for both the categories of farms at state level was estimated on the basis of the proportion of area under each crop observed for each category in the sample during 1981-82.

3. Since the total area under different crops estimated above was little different from the actual figures at the state level, this was rationalized with the help of ratios between actual and estimated area under different crops (**Table 3**). It was further assumed that 10% of the area of the state under paddy and wheat was harvested and threshed with combine harvesters in 1981-82.

4. In order to project the demand for human labour in crop production for the year 1995-96, the gross cropped area for the same year was projected in the following manner: The gross cropped area was perceived to gain 75% of the rate of increase observed during 1981-82 through 1985-86 for the period 1986-87 through 1990-91, while this rate of increase was assumed to be at 50% in place of 75% during 1991-92 through 1995-96 because the scope of further expansion in cultivated area in the state is limited. Thus, the gross cropped area of the state was projected at 7 482 500 hectares for the year 1995-96.

5. The number of tractors for the year 1995-96 was projected by extending a linear trend estimated in this regard for two sets of periods viz., 1974-75 through 1984-85 and 1980-81 through 1984-85. Both periods provided almost similar projectd estimates for 1995-96, thereby indicating that the number of trctors in the state is increasing at a constant rate. On this basis, the number of tractors in the state was estimated at 284049 units in the year 1995-96.

6. The gross cropped area projected in step 4 was distributed under BOFs and TOFs following the procedure detailed in step

1 which was estimated at 2 555 670 and 4 926 830 ha, respectively.

7. The projections relating to the cropping pattern for the year 1995-96 were made by following two approaches as explained below:

a. The gross cropped area under each category of farms projected under step 6 was allocated to different crops assuming the same proportions of area (**Table 4**) under these crops estimated for the year 1981-82 under step 3.

b. Under the second approach, the cropping pattern for the year 1995-96 at state level was developed by considering the recommendations of the Expert Committee Report on Diversification of Agriculture in Punjab[1].

According to the recommendation of this committee, a shift of 20% of area from paddy and wheat to sugarcane, oilseeds, pulses, vegetables and fodder crops was contemplated. The allocation of gross cropped area under different crops was made in the light of these recommendations.

Further, the ratios of area between bullock farms and tractor farms for each crop were estimated from step 7 (a). By holding these ratios constant for each crop, the area under different crops projected on the basis of recommendations, was split up between BOFs and TOFs (**Table 5**).

In both cases, 25% of the area under paddy and wheat crops of the state was assumed to be harvested and threshed by harvesting combines on the basis of past trend.

8. The labour use coefficients for different crops for BOFs and TOFs estimated from the sample during 1981-82 were considered to hold good for the year 1995-96 assuming that there will not be any technological change affecting labour coefficients during this period (**Table 2**).

1 For details see Report of the Expert Committee on Diversification of Agriculture in Punjab, Government of Punjab, 1986.

Table 3 Area and Demand for Human Labour under Different Crops on Bullocdk Farms and Tractor Farms in Punjab State, 1981-82

Crop	Area in thousand ha				Demand in million man-day			
	Bullock farms	Tractor Farm		Total	Bullock farms	Tractor Farm		Total
	BOF	TOF	T+CHr		BOF	TOF	T+CHr	
Paddy	731.07	411.03	126.90	1269.00	94.315	43.228	9.859	147.402
Wheat	1884.19	738.41	291.40	2914.00	106.852	36.034	5.525	148.411
Cotton (Am)	431.50	114.50	N.A.	546.00	42.775	12.361	N.A.	55.136
Cotton (Desi)	102.63	37.37	N.A.	140.00	14.449	4.341	N.A.	18.790
Maize	266.95	113.05	N.A.	340.00	18.728	6.742	N.A.	25.470
G. Nut	63.65	28.35	N.A.	92.00	5.021	2.108	N.A.	7.129
S. Cane	63.51	40.49	N.A.	104.00	9.250	7.461	N.A.	16.711
Gram	209.98	33.02	N.A.	243.00	8.955	1.395	N.A.	10.350
Other pulses	55.21	26.79	N.A.	82.00	2.415	1.034	N.A.	3.449
Barley	72.32	15.68	N.A.	88.00	3.519	0.750	N.A.	4.269
Rape. & must.	65.35	44.65	N.A.	110.00	4.880	3.171	N.A.	8.051
Potato	15.83	20.17	N.A.	36.00	2.497	2.620	N.A.	5.117
Fodder	495.32	204.68	N.A.	700.00	38.560	13.873	N.A.	52.443
Other veg.	N.A	N.A.	N.A.	40.69	N.A.	N.A.	N.A.	6.976
Total	4639.46	1871.24	418.30	6929.00	352.216	135.118	15.384	509.694

Area under vegetables for different farm categories was negligible. Therefore, it was not possible to distribute it among them
Source: Statistical Abstracts of Punjab.

Table 4 Area and Demand for Human Labour under Different Crops on Bullocdk Farms and Tractor Farms in Punjab State, 1995-96

Crop	Area in thousand ha				Demand in million man-day			
	Bullock farms	Tractor farm		Total	Bullock farms	Tractor farm		Total
	BOF	TOF	T+CHr		BOF	TOF	T+CHr	
Paddy	402.77	769.29	390.02	1560.08	51.961	80.696	30.300	162.957
Wheat	1037.86	1402.23	813.36	3253.45	58.857	68.429	15.421	142.707
Cotton (Am)	237.68	246.34	N.A.	484.02	23.561	26.595	N.A.	50.156
Cotton (Desi)	56.48	80.31	N.A.	136.79	7.952	9.329	N.A.	17.281
Maize	124.97	243.38	N.A.	368.35	10.313	14.515	N.A.	24.828
G. Nut	35.01	61.09	N.A.	96.10	2.761	4.544	N.A.	7.305
S. Cane	35.01	87.20	N.A.	122.21	5.099	16.068	N.A.	21.167
Gram	115.77	70.95	N.A.	186.72	4.937	2.997	N.A.	7.934
Other pulses	30.41	57.64	N.A.	88.05	1.330	2.224	N.A.	3.554
Barley	39.87	33.50	N.A.	73.37	1.940	1.603	N.A.	3.543
Rape. & must.	36.03	96.07	N.A.	132.10	2.691	6.823	N.A.	9.514
Potato	8.69	43.36	N.A.	52.05	1.371	5.632	N.A.	7.003
Fodder	272.69	440.46	N.A.	713.15	21.223	29.854	N.A.	51.077
Other veg.	N.A.	N.A.	N.A.	44.15	N.A.	N.A.	N.A.	7.569
Total	2555.67	3723.45	1204.38	7482.50	193.996	269.309	45.721	516.595

Area under vegetables for different farm categories was negligible. Therefore, it was not possible to distribute it among them.

9. The demand for human labour for the years 1981-82 and 1995-96 was estimated by multiplying the area in hectares under each crop with the corresponding labour days required per hectare.

Tables 2, 3 and **4** also detail the result of this exercise. The demand for human labour for the year 1981-82 was estimated at 509.69 million man-days (**Table 3**) which was expected to increase to 516.59 million man-days in the year 1995-96 (**Table 4**). Further, this demand for labour amounted to 544.95 million man-days for the year 1995-96 following the recommendations of the Expert Committee on Diversification of Punjab Agriculture (**Table 5**). The increase was equivalent to 6.92% over 1981-82. The demand for

Table 5 Area and Demand for Human Labour under Different Crops on Bullocdk Farms and Tractor Farms in Punjab State on the basis of Recommendations of Expert Committee on Diversification of Agriculture, 1995-96

Crop	Area in thousand ha				Demand in million man-day			
	Bullock farms	Tractor Farm		Total	Bullock farms	Tractor Farm		Total
	BOF	TOF	T+CHr		BOF	TOF	T+CHr	
Paddy	265.65	505.98	257.21	1028.84	34.271	53.214	19.982	107.467
Wheat	810.12	1094.55	634.89	2539.56	45.942	53.414	12.037	111.393
Cotton (Am)	333.95	346.05	N.A.	680.00	33.105	37.359	N.A.	70.464
Cotton (Desi)	51.61	73.39	N.A.	125.00	7.266	8.525	N.A.	15.791
Maize	92.15	179.45	N.A.	271.60	7.604	10.702	N.A.	18.306
G. Nut	16.76	29.24	N.A.	46.00	1.322	2.175	N.A.	3.497
S. Cane	84.52	210.48	N.A.	295.00	12.310	38.785	N.A.	51.095
Gram	62.01	37.99	N.A.	100.00	2.645	1.605	N.A.	4.250
Other pulses	51.81	98.19	N.A.	150.00	2.267	3.789	N.A.	6.056
Barley	26.08	21.92	N.A.	48.00	1.269	1.049	N.A.	2.318
Rape. & must.	81.84	218.16	N.A.	300.00	6.112	15.494	N.A.	21.606
Potato	11.69	58.31	N.A.	70.00	1.845	7.574	N.A.	9.419
Fodder	539.18	870.82	N.A.	1410.00	41.975	59.024	N.A.	100.999
Other veg.	N.A.	N.A.	N.A.	130.00	N.A.	N.A.	N.A.	22.287
Total	2506.16	3911.45	892.10	7309.71*	197.933	292.709	32.019	544.948

*Total cropped area in this case was reduced to 7309.71 thousand hectares because an additional area of 172.79 thousand hectares was brought under sugarcane.
Area under vegetables for different farm categories was negligible. Therefore, it was not possible to allocate it separately under them.
Source: Report of Expert Committee on Diversification of Agriculture in Punjab, Government of Punjab, 1986.

labour was estimated at 472.5 million man days in 1974-75 (Bal et al, 1979)[2]. It is interesting to observe that the labour use increased over time despite increased tractorization and introduction of harvesting combines on 25% of the area under paddy and wheat crops. This happened due to the increase in gross cropped area from 6 929 000 ha in 1981-82 to 7 286 000 ha in1995-96 and shifts in favour of labour intensive crops like sugarcane, vegetables and fodder.

Some Policy Issues

The choice of technology is one of the key instruments of a development strategy. A vigorous debate has been going on regarding the choice of appropriate technology for developing countries with reference to its employment implications. Since the agriculture sector is the backbone of Punjab economy contributing a share of about 52% to Gross State Domestic Product and providing employment to about 59% of the total work force, the question of technological choice in agriculture is, therefore, of fundamental importance for resource allocation and employment policy in Punjab. There have been significant technological changes taking place in Punjab agriculture, e.g., the adoption of high yield varieties of seeds, higher use of fertilizers and other chemical inputs and assured irrigation. farm mechanization, especially tractorization, has also made a headway in the state

From the policy point of view, the whole problem of farm mechanization vis-à-vis human labour employment can be examined from three angles: (i) does farm mechanization along with other inputs enhance agricultural production ?; (ii) to what extent has labour been displaced ?; and (iii) what policies should be followed to harness the gains of new production technology while minimizing the undesirable effects of labour displacement, if any?

The process of farm mechanization was hastened in Punjab as a consequence of rapid adoption of seed-irrigation-fertilizer technology and the system of multiple cropping following the Green Revolution. Thus the number of tractors in the state increased unprecedentedly during the last 15 years. Agricultural production index with 1969-70 as base, rose from 109.8 in 1970-71 to 239.3 in 1985-86 due to the higher use of commercial inputs, increase in area under irrigation, higher cropping intensity and greater use of mechanical power on the farms. The present study also supported the above findings. This showed that the level of output was higher on TOFs as compared to BOFs due to higher use of mechanical as well as chemical input. But in spite of this there was no significant difference in human labour use per hectare of cultivated area between BOFs and TOFs. Higher cropping intensity, higher level of inputs use and higher level of output fully compensated for the replacement of human labour for the operations where tractor was used (**Table 1**). As estimated earlier, demand for human labour in the agriculture sector increased from 472 510 000 man-days in 1974-75 to 509 690 000 man-days in 1981-82 registering an increase of about 8%. It is expected to rise further to 544 950 000 man-days by 1995-96.

Due to the adoption of modern technology on large scale and increase in productivity, agriculture sector of the state started experiencing labour shortages in peak work periods and began to attract labour from other states like Uttar Pradesh, Bihar, Madhya Pradesh, Orissa, Rajasthan, etc. Migrant labour force in Punjab was about 150 000 persons in 1977-78, which constituted about 5% of the total agricultural labour force. It swelled to 286 000 persons in lean period to 570 000 persons in peak work periods. This was estimated to be about 9.5% of the total agricultural labour force

2 Bal, H.S., Bant Singh and H.K. Bal., "Surplus Farm Labour in Punjab" Agricultural Situation in India Vo. 33 (12): 795-801.

in lean periods and about 19% in peak work periods[3].

Harvesting combines are now used to meet the labour demand in peak work periods for wheat and paddy to avoid delay in harvesting of these crops, which affects the timely sowing and productivity of the subsequent crops. Since the use of harvesting combines significantly reduces the labour requirements of wheat and paddy, it is necessary that the process of their adoption is properly monitored and controlled to avoid social costs of labour displacement. At present there are about 2 000 self-propelled and 20 000 tractor-drawn harvesting combines in the state. The scope of their further expansion depends upon the expansion of area under wheat and paddy, availability of harvestable area for using combines, availability of manual labour, demand for dry fodder, etc. Due to the predominance of wheat-padddy rotation, which has led to some serious ecological, production and marketing problems in the state. The government of Punjab is making serious efforts to diversify the cropping pattern of the state replacing cereals. Therefore, a likely significant shift in area from wheat and paddy to other crops will restrict the scope of harvesting combines. Secondly, the area available for harvesting through combines is limited because majority of the farmers are small and marginal, who have adequate family labour at their command for harvesting the crops. Besides, increase in the inflow of migrant labour in the state has eased the scarcity of human labour in peak work periods thereby limiting the scope of harvesting combines. In recent years, shortages of dry fodder and the consequent higher prices has further restricted the use of combines for wheat crop. Thus, the demand for harvesting combines in the state is not expected to expand very significantly in the coming years.

On the other hand, tractorization became an important component of package of inputs, more out of technical necessity than for reasons of substitution of capital for labour on the pattern of western agricultural model where labour is very scarce. As speculated by many, the rate of growth in tractors has not diminished significantly over time. It was 16% per annum during 1975-76 to 1980-81 and 14% per annum during the period 1981-82 to 1986-87. This phenomenal growth in tractor number was witnessed despite sharp increase in tractor prices. With 1970-71 as base, the price index of tractors increased to 356 and that of fuel oil prices to 800 in 1983-84. Compared to this, the price index of paddy rose only to 250, wheat to 199, desi cotton to 312 and American cotton to 174 only during this period[4]. At present, more than 25% of the operational holdings have tractors as their main source of draft power in Punjab assuming that not more than one tractor was owned by any one holding. About another 50% of holdings comprising mainly of marginal, small- and medium-sized farmers supplement their animal draft power with tractors on custom hiring basis during the peak period of field preparations. BOFs, on an average, use tractors for 2.65 h per hectare (**Table 1**). Thus there exists further demand for tractors in the state provided small, low-horse power and cost effective low priced tractors are available, which may be within the purchasing power of the small and medium-sized farmers.

The experience of the state shows that mechanization is a part of the dynamics of agriculture development for improving resource efficiency and productivity of agriculture. The development process of substituting mechanical inputs for human labour is not primarily the result of rising wage rates and increasing cost of animal draft power but revolves around the problem of serious labour shortages during peak work load labour periods arising from the adoption of new production technology. The significant increase in production and cropped area can offset the labour-displacing effect of selective mechanization and that is exactly what has actually happened in Punjab agriculture. If the generation of off-farm employment in the manufacturing, distribution and servicing and repairing of tractors and harvesting combines is taken into account, the cumulative increase in employment would far exceed the on-farm labour displacement of human labour, if any.

Diversification of Punjab agriculture as envisaged in favour of labour intensive crops such as sugarcane, vegetables and fruits, fodder crops, etc. can also help increase labour employment in addition to restoring ecological balance of the state.

The analysis, however, shows that demand for labour in Punjab may not grow enough in the future to absorb the growing labour force. Ultimately the development process involves transfer of labour from the primary sector to the secondary and tertiary sectors of the economy. Therefore, solution to the problem of disguised and open unemployment lies in creating employment opportunities in the secondary and tertiary sectors of the economy. ■■

3 Sidhu, M.S. & S.S. Grewal (1984), "A Study on Migrant Labour in Punjab", Department of Economics, Punjab Agricultural University, Ludhiana.

4 Sidhu, H.S. (1987), "Tractor distribution system in the Punjab state" M. Sc. Thesis (Unpublished), Department of Economics, PAU, Ludhiana.

Development and Field Performance of a Chickpea Thresher


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Abstract

A multi-drum thresher consisting of three raspbar cylinders, delivery augers, rubber flap elevator, aspirator fan for cleaning, and oscillating screen was developed. The machine was powered from the tractor's PTO and mounted on tractor's 3-point linkage for transport. Test results during the 1988 chickpea harvest showed that the machine had an average intake crop capacity of 1500 kg/h and a cleaning efficiency of 94%. Grain damage was 8.5% and grain loss was 3%. Two men were required to operate the machine.

The thresher was also tried for other crops like soybean, sunflower and safflower. The average grain damage for these crops was 1.5%, 1.1% and 0.5%, respectively.

The chickpea thresher performance was compared with conventional threshing using bullock and tractor treading followed by manual winnowing, in terms of grain losses and labour requirement. The labour requirement to thresh one ton of grain using the thresher was 89% and 76% less than the values obtained for bullock and tractor treading followed by manual winnowing.

Introduction

Chickpea or gram (*Cicer arietinum* L.) is a popular source of protein in many Asian countries. It is cultivated as a winter crop in the tropics and a spring or summer crop in the temperate climate. The annual world production of chickpea is about 7 million tones of dry grains from an area of about 10 million hectares. Eighty-five percent of the total production comes from South Asia but the cropping area extends westwards from Afghanistan through West Asia and the Mediterranean basin, into Ethiopia and East Africa, the Americas and Australia (1).

Chickpea is grown as postmonsoon "winter" crop in Pakistan. By land area planted to chickpea, the country ranks second in the world. The total production of grain legumes in 1987-88 was 556 100 tones, of which chickpea alone contributed about 69%. In 1987-88, the national average yield was 453 kg/ha (2). The maximum yield of 5 000 kg dry seed of chickpea per hectare was obtained in India or winter sown crops in the Mediterranean.

Traditionally, chickpea harvesting and threshing is done manually. After harvest, the plants are left in the field for 3-4 days in small piles for drying and later gathered into large heaps in the threshing yard. Almost 100% of chickpea crop is threshed by animals, tractor treading or flailing by poles. Mechanical threshers are not used in Pakistan (1).

The optimum time of chickpea harvesting and threshing in Pakistan is April-May, overlapped by wheat harvesting and threshing (3). The threshing with bullock or tractor treading and subsequent manual winnowing is a labour-intensive operation, hence there is need for a mechanical thresher for chickpea for efficient and timely threshing.

Literature Review

Vas et al (4) investigated the effects of mechanical threshing parameters on kernel damage and threshability of small grains. The cylinder speed was the primary influencing parameter; while concave clearance, although of less significance, was an important factor as well.

Majumdar (5) designed a multicrop thresher by incorporating IRRI axial flow arrangement on traditional tooth thresher for threshing chickpea, wheat, sorghum, maize and paddy. Threshing studies onchickpea showed that grain losses were 2% with threshing efficiency of 99%.

Amjad et al (6) tested an axial flow peg tooth thresher for its performance on CM-72 chickpea variety for limited hours of operation. The average percentage of grain loss, threshing and cleaning efficiencies were recorded to be 5.6%, 95.8% and 91.4%, respectively. It was suggested that the thresher should be extensively tested for varied crop and machine parameters. Anwar (7) tested extensively the same thresher on chickpea (CM-72). It was observed that cylinder speed, feed rate and cyulinder concave clearance effected the thresher performance in terms of grain damage, total machine loss, threshing and cleaning efficiencies. It was observed that the thresher had maximum crop intake capacity of 380 kg/h due to difficult feeding, hence resulting in low grain output. Therefore, the study suggested that raspbar threshing system with easy feeding method should be tested for chickpea threshing.

Objectives

The study was undertaken with the following objectives:

1. To develop a suitable chickpea thresher based on raspbar threshing system;
2. To measure the field performance of chickpea thresher; and
3. To make recommendations for possible modifications of the thresher for improved performance.

Materials and Methods

Development of Thresher

The chickpea thesher **(Fig. 1)** is a modified version of threshing system of whole crop harvester **(Fig. 2)**. The whole crop harvester has been developed in collaboration with the Agricultural and Food Research Council (AFRC) Institute of Engineering Research (formerly known as National Institute of Engineering Research), UK, in 1984. The machine was first tested in Pakistan in 1985. A second prototype was built with a cleaner in 1987. A local manufacturer built and tested its two units in 1988. The whole crop harvester has been developed primarily to harvest the whole wheat crop, producing clean grain and finely broken straw called "bhoosa" for animal feed.

In 1987, the work was initiated on the identification of suitable design of thresher for chickpea based on raspbar threshing cylinder. Keeping in view the performance of whole crop harvester on other crop, it was recommended that with some modifications the threshing system of the whole cropharvester can be used for threshing chickpea. The threshing system of 1985 whole crop harvester prototype was modified to use it as a stationary thresher for chickpea threshing during 1988.

Modifications

The thresher assembly of the whole crop harvester comprises of three drums. Drum 3, which is meant for straw breaking in whole crop harvester was replaced with a scavenging drum **(Fig. 3)** in order to complete the threshing and separation process of left-over pods from drum 2.

Fig. 1 Chickpea thresher during field operation.

Fig. 2 Whole crop harvester.

The concave surrounding drum 3 closed with fixed breaker bars is replaced with a 160° open concave to ensure shifting of the leftover grains.

An outlet deflector, stripper tube and shroud is added to ensure proper exit of straw from drum 3 outlet.

An adjustable deflector plate is added to control the quantity of crop being conveyed from drum 2 to drum 3.

A bolt on chute under drum 3 is added to guide the leftover grains to be conveyed to elevator through auger 1.

Instead of the table assembly, a hand feeding hopper is used for manual feeding of the crop.

Description of Thresher

The thresher **(Fig. 4)** is a tractor PTO-operated machine, comprising mainly of threshing and cleaner assemblies. The machine is

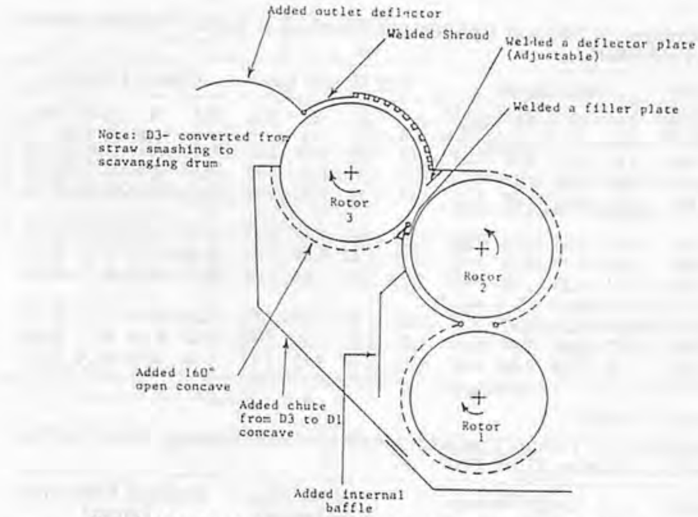

Fig. 3 Modified line diagram of chickpea threshing system.

designed for direct mounting on tractor's 3-point linkage (Cat II).

The threshing system consists of three raspbar drums, acting on radial bar open concaves which thresh and separate the grain from stem material. The crop is fed in the feeding hopper where it passes under twin chain crop elevator, over a stone trap and goes to the first drum. Drum 1 mainly threshes and separates the grain. Drum 2 continues the threshing and commences the straw breaking process. Drum 3 completes the threshing of the remaining material and straw smashing and throwing process. Drums 1 and 2 run over 360° of special concave, designed to maximize straw breaking and separation. Whereas, drum 3 runs over 160° of open concave.

Threshed grain and chaff passing through concaves 1, 2 and 3 is conveyed by augers 1 and 2 to a chain flap elevator which elevates the material to the cleaner.

The cleaner comprises a winnowing section where the light material, including dry leaves and threshed pods, are drawn out by a centrifugal fan and blown to the ground. The heavy material passes to the second section comprising of oscillating sieve assembly. The grain passes through its screen on to the grain pan which discharges into the grain bagging auger. At the point of discharge the grain gets a final cleaning by an air stream from the secondary air column. Unthreshed material passes over the screen and is returned to drum 1 for rethreshing.

Power is transmitted through chain-sprockets and B-section V belts to the threshing drums, delivery augers, cleaning fan, intake elevator and sieve assembly (**Fig. 5**).

The cylinder-concave clearance can be adjusted from 8 mm to 16 mm depending on crop condition through the concave adjusters.

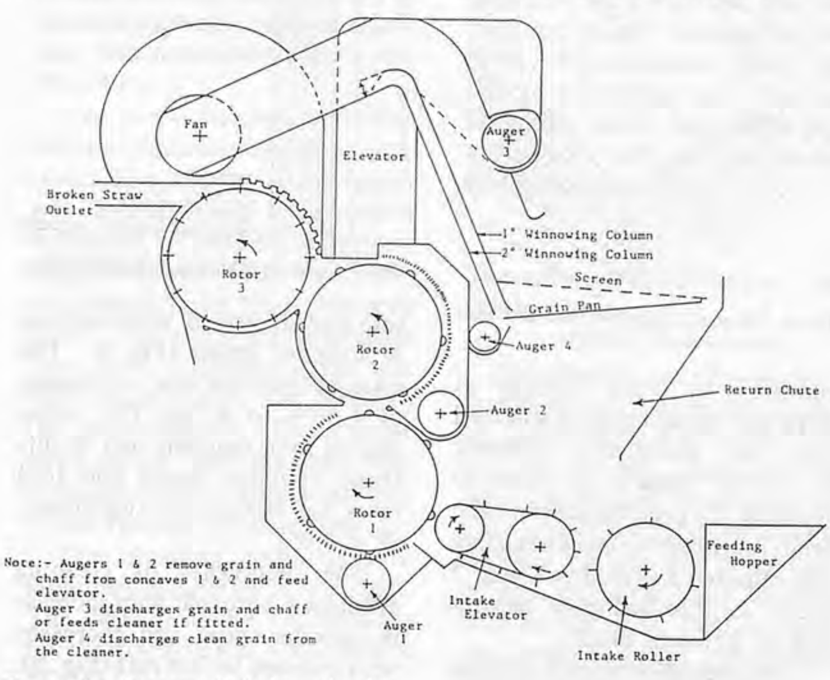

Fig. 4 Line diagram of chickpea thresher.

Field Performance Test

The variables considered for field testing of the thresher were: three threshing cylinder speeds (9.2, 10.5 and 11.0 m/s) and three feed rates (936, 1055 and 1540 kg/h). The cylinder-concave clearances were kept constant for all combinations of cylinder and feed rates. Only one chickpea variety C-44 was threshed.

Total machine loss in threshing

Fig. 5 Power transmission of chickpea thresher.

operation included fan loss, unthreshed pods and thrower loss. It is expressed as:

$$L_T = L_F + L_{TH} + L_{UT}$$

where:
L_T = Total machine loss, %
L_F = Fan loss, %
L_{TH} = Thrower loss %
L_{UT} = Unthreshed loss %

The grain damage was also observed at the main grain outlet. It is expressed as:

$$G_D = (Wd/Wi) \times 100$$

where:
G_D = Grain damage, %
Wd = Weight of damaged grain, gm
Wi = Total grain input, gm

Field performance of the thresher was compared with the conventional methods (threshing using bullocks and tractor treading) in terms of grain losses and labour requirement.

Results and Discussion

The data collected during the course of investigation was analysed using analysis of variance for thresher performance in terms of grain damage, total machine loss and cleaning efficiency. The scientific package MSTAT (V-4.0) with RCBD 2 Factor Factorial subprogramme (8) was used.

Table 1 presents the thresher performance at different combination of variables. Percentiles of grain damage increased with increase in cylinder speed and decreased with increase in feed rate **(Fig. 6)**. Grain damage was in the range of 3.8% to 13.13%. the high grain damage was due to the fact that the cylinder-concave clearance could not be adjusted according to the grain size. The

Table 1 Performance of Thresher for Chickpea Threshing at Various Cylinder Speeds and Feed Rates

Cylinder Speed (m/s)	Feed Rate (kg/h)	Grain Damage				Total Machine Loss				Cleaning Efficiency			
		R1	R2	R3	Avg.	R1	R2	R3	Avg.	R1	R2	R3	Avg.
9.2	936	5.47	4.13	6.20	5.27	4.95	3.95	2.99	3.96	91.56	93.63	91.64	92.28
	1055	4.98	3.92	4.10	4.30	3.75	4.39	4.30	4.15	90.89	90.08	87.76	89.58
	1540	3.57	4.22	3.86	3.88	4.77	4.73	4.66	4.72	85.82	89.34	90.05	88.40
10.5	936	10.55	11.35	12.74	11.55	2.33	2.80	1.83	2.32	92.71	91.83	92.39	92.31
	1055	7.09	10.11	11.38	9.49	2.78	2.63	3.09	2.83	89.96	91.12	91.11	90.73
	1540	5.71	6.25	7.59	6.52	5.72	4.19	4.09	4.67	88.29	89.96	88.79	89.01
11.0	936	16.29	12.24	10.87	13.13	2.00	1.96	1.99	1.98	92.59	93.66	94.22	93.49
	1055	11.72	10.02	9.67	10.47	1.26	2.45	3.56	2.42	92.23	91.59	94.17	92.66
	1540	7.66	7.29	4.96	6.64	3.22	3.73	3.15	3.37	93.86	93.14	90.36	92.45

Table 2 Comparison of Various Treatment Means for Grain Damage, Total Machine Loss and Cleaning Efficiency

Treatment	Grain Damage (mean)	Total Machine Loss (mean)	Cleaning Efficiency (mean)
S1F1	5.27 cd	3.96 abc	92.28 ab
S1F2	4.30 cd	4.15 ab	89.58 cd
S1F3	3.88 d	4.72 a	88.40 d
S2F1	11.55 ab	2.32 de	92.31 ab
S2F2	9.49 b	2.83 cde	90.73 bc
S2F3	6.52 cd	4.67 a	89.01 cd
S3F1	13.13 a	1.98 e	93.49 a
S3F2	10.47 b	2.42 de	92.66 ab
S3F3	6.64 c	3.37 bcd	92.45 ab

S1 = 9.2 m/s, S2 = 10.5 m/s, S3 = 11.0 m/s; F1 = 936 kg/h, F2 = 1055 kg/h, F3 = 1540 kg/h
Note: In a column, any means followed by the same letter are not significantly different at 5% probability level.

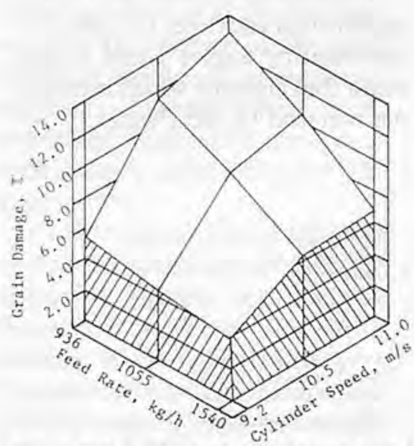

Fig. 6 Effect of cylinder speed and feed rate on grain damage.

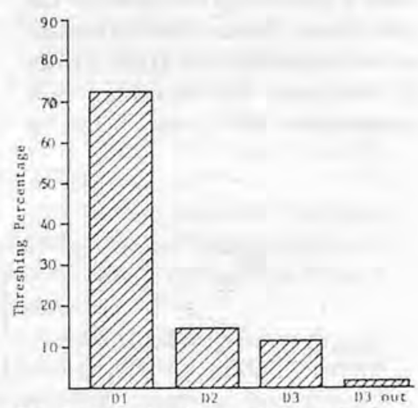

Fig. 7 Grain threshing at different drums.

variation in grain damage at different cylinder speeds and feed rates was statistically different ($P < 0.05$) **Table 2**. In order to ascertain the performance of each drum for threshing chickpea, data was collected and analysed. **Fig. 7** shows the threshed grain percentage at different drums.

The percentiles of total machine loss increased with increase in feed rate and decreased with increase in cylinder speed **(Fig. 8)**. The total machine loss was in the range of 1.98% to 4.7%. The variation in total machine loss at different cylinder speeds and feed rates was statistically significant, ($P < 0.05$).

The percentiles of cleaning efficiency increased with increase in cylinder speed and decreased with increase in feed rate **(Fig. 9)**. Cleaning efficiency was in the

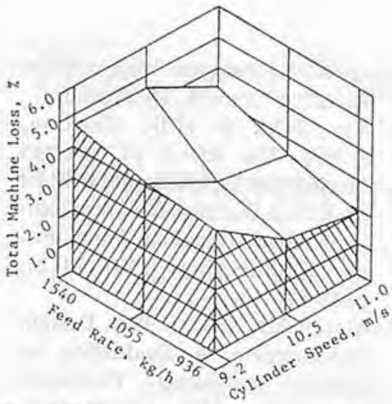

Fig. 8 Effect of cylinder speed and feed rate on total machine loss.

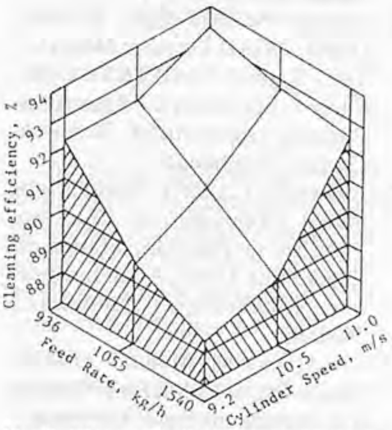

Fig. 9 Effect of cylinder speed and feed rate on cleaning efficiency.

range of 88.4% to 93.5%. The variation in cleaning efficiency at different cylinder speeds and feed rates was statistically significant, ($P < 0.05$).

The straw samples were also taken at different drums and analysed. The average straw length was 72.1, 70.6, 64.8 mm at drums 1, 2 and 3, respectively. The straw length was quite large and farmers wanted more finely chopped starw. Therefore, the semi-axial flow straw smashing drum was tried out at NARC and collected the straw samples. The average straw length with this drum was 27.6 mm which is quite acceptable to the farmers as camel feed.

The thresher required two labourers to operate in the field. The average labour requirement for the machine was 4 man-h/ton of clean grains.

Table 3 Labour Requirement for Traditional Threshing System (Bullock and Tractor Treading)

Operation	Labour Requirement (man-h/t)	
	Bullock treading	Tractor treading
Spreading of crop on Threshing floor	2.0	2.0
Threading	18.0	3.0
Winnowing and cleaning	9.0	9.0
Collecting and bagging	3.0	3.0
Total	32.0	17.0

Table 4 Performance of Chickpea Thresher for Threshing Different Varieties of Soybean, Sunflower and Safflower

Parameters	Soybean Varieties						Sun-flower	Saf-flower
	S-69-94	PSC62	Ransen	IDB 204-77	Davis	Williams		
Drum speed (m/s)	9.7	10.2	10.5	10.0	11.0	11.9	9.8	10.5
Grain damage (%)	1.1	0.4	1.7	0.4	0.7	5.1	1.1	0.5
Unthreshed grain (%)	2.3	1.7	—	—	0.4	0.3	—	—
Threshing efficiency (%)	97.7	99.2	100.0	100.0	99.7	99.7	100.0	100.0
Cleaning efficiency (%)	91.5	95.6	95.5	96.2	88.3	94.2	95.4	

Traditional Threshing

Bullock treading and tractor treading followed by manual winnowing are the two traditional methods. The labour requirement for these two traditional systems are compared in **Table 3**. The total grain losses of 11.9% and 12% were recorded for bullock and tractor treading respectively. The maximum grain loss was in winnowing and cleaning operation which was 9.9% and 9.5% for bullock and tractor treading, respectively.

Thresher Performance on Other Crops

The thresher was also tested for threshing other crops like soybean, sunflower and safflower. The cylinder-concave clearance and sieve was changed according to the grain size of crop. Six varieties of soybean and one each of sunflower and safflower were threshed with the thresher. **Table 4** shows the performance of thresher for threshing these crops.

Conclusions

1. The grain damage was in the range of 3.8% to 13.1%. The grain damage increased with increasing cylinder speed and decreased with increasing feed rate.
2. The total machine loss was in the range of 1.98% to 4.7%. The total machine loss increased with increasing feed rate and decreased with increasing cylinder speed.
3. The cleaning efficiency was in the range of 88.4% to 93.5%. The cleaning efficiency increased with increasing cylinder speed and decreased with increasing feed rate.
4. The crop intake capacity was in the range of 936 kg/h to 1540 kg/h. The grain output depends on the grain straw ratio of crop.
5. On an average, the straw coming out of the thresher was 72.1 mm long. Farmers were demanding finer straw, because they use it as camel feed.
6. The labour requirement to thresh 1 t of grain using the

thresher was 4 man-h, which was 89% and 76% less than the values obtained for bullock and tractor treading followed by manual winnowing, respectively, i.e., 32 and 17 man-h.
7. The thresher was also used for threshing soybean, sunflower and safflower. Grain damage was 1.6%, 1.1% and 0.5% with cleaning efficiency of 94.3%, 94.2% and 95.4% for soybean, sunflower and safflower, respectively.

Recommendations

1. Due to greater demand of fine straw it is recommended that the scavenging drum (D3) should be replaced with a semi-axial flow straw smashing drum.
2. The cylinder-concave clearance adjustment mechanism should be modified for easy adjustments.
3. For optimal operational parameters, the thresher should be tested for various crop and machine parameters.
4. The thresher should also be extensively tested for other crops, like soybean, sunflower, safflower and sorghum to ascertain its adaptability for the crops.
5. The economics of the thresher operation should be compared with the existing threshing systems.

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Draft and Energy Requirements of Agricultural Implements in Semi-arid Regions of Morocco

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Abstract

An agricultural tractor was instrumented so that draft, travel speed and fuel usage could be messured for six different agricultural tillage implements used in the semi-arid regions of Morocco: tandem disk, chisel plow, disk plow sweep and an offset disk. These implements were tested under three different soil conditions and a range of travel speeds and tillage depths. A summary of the results in terms of draft, energy requirements and fuel usage for each implement operating at different depths is included. Choices in selection of tillage implements, whose use have approximately the same end result, are available and can result in more economical tillage operations.

Introduction

Draft and energy requirements for agricultural implements have long been recognized as essential data when attempting to correctly match an agricultural implement and tractor. Presently, there is no data base available on draft and energy requirements of agricultural implements in Morocco. Lack of this data inhibits good economic evaluations of tillage systems used in production agriculture in Morocco.

Acknowledgement: The authors acknowledge the support for this research from USAID Project No. 608-0316.

Objective

The objective of this research was to obtain draft and energy requirements of some common primary and secondary tillage implements used in the semi-arid regions of Morocco.

Review of Literature

Numerous draft and energy studies of tillage equipment have been conducted throughout most of the United States. Results of early studies emerged in the 1930's and have continued where now more attention is being focused on the economics of energy conservation.

The effect of travel speed on implement draft depends on the soil type and the type of implement. Ashby et al (1932), Randolph et al (1938), Collines et al (1978), and Bloome et al (1983) relate draft of a moldboard plow by a parabolic relationship to travel speed for a variety of soil types and speed ranges from 1.6 to 9.7 km/h. For chisel plows, Bloome et al (1983) concluded that the response of implement draft to speed is linear for a speed range of 4 to 10 km/h. Reed (1948) reports a linear relationship of draft and speed for disk plows operated at 4 to 8 km/h. Experiments by Bloome et al (1983) indicated different coefficients of regression in unit draft equations between a chisel plow equipped with points and one equipped with sweeps in a silt loam soil. They concluded that separate unit draft equations were required when using chisel points and when using sweeps.

Draft of disk harrows was different depending whether they were used as a primary tillage implement or a secondary tillage implement. Krishnan et al (1988) reported that the specific draft of a tandem disk harrow used for primary tillage can be expressed as a quadratic function of speed. In a secondary tillage operation, specific draft was expressed as a linear function of speed. Summers et al (1986) reported that draft dependency from a disk harrow was linear with speed. Bloome et al (1983) concluded that disk harrow draft can sufficiently be predicted as a linear function of speed. Using V-blades, he also found a quadratic relationship between draft and speed for a silt loam soil and a linear relationship for a fine loamy sand soil. Both soils had similar cone index values.

Some researchers agree that the normal operating travel speeds of implements fall into a transition zone for linear and parabolic responses of implement draft to speed, due to the action of the shearing planes in the soil. Historically, Randolph et al (1938) reports "the factor of speed, within the variation of mule farming, has little effect on machine draft."

Depth has an obvious effect on implement draft, although its relationship has only recently been investigaed. Collins et al (1978) reported depth to be a linear function of draft for moldboard and chisel plows. Garner and Wolf (1981) investigated different zone layers of soil for a subsoiler. They showed that a linear relationship existed between draft and depth within each soil zone. Gunderson et al (1981) was interested in depth control of implements, and showed draft to be a quadratic function of depth for a field cultivator.

The American Society of Agricultural Engineers (ASAE) regularly includes implement draft data as part of their annual standard publication. The ASAE Data: ASAE D230.4 Agricultural Machinery Management Data represents the efforts of many individuals over the years. Much of the information has come from various state agricultural experiment stations. The data are presented in equation form, and predict total implement draft or specific draft of common implements. Travel speed, tillage depth or implement mass appear in the equations as an independent variable. The general form of the equation is:

$$y = a + b*x + c*z$$

where x and z are the independent variables, a, b and c are regression coefficients and y is the draft.

Procedure

A Massey Ferguson 290 manual shift tractor was instrumented such that drawbar pull and travel speed of attached implements could be measured. Transducers were designed and built so that the drawbar pull of towed or mounted implements could be measured. The instrumentation package included signal conditioning for strain gage and frequency transducers and a portable lap-top computer for data storage. A fuel flow meter was used to measure volumetric flow of diesel fuel to the engine while obtaining draft data. Specific details of the instrumentation system are given by Byerly (1989).

Six different common tillage implements used in the semi-arid regions of Morocco were evaluated for draft requirements over a wide range of travel speed and depths. The tillage implements tested were;

1. a rear-mounted tandem disk harrow, 2.96 m width,
2. a rear-mounted chisel plow equipped with gage wheels and sweeps, 9 shanks, 2.48 m width,
3. a rear-mounted chisel plow equipped with gage wheels and points, 9 shanks, 2.48 m width,
4. a two-blade rear mounted disk plow, 0.85 m width,
5. a prototype three-shank sweep, 2.73 m width,
6. a offset disk harrow with a drag type pull hitch, 2-2.2 m width depending on the gang angle.

The ASAE Standard: ASAE S414 Terminology and Definitions for Agricultural Tillage Implements was used as the reference to designate the tillage equipment tested.

Data were collected on research stations located at Sidi El Aydi and Khemis Zemamra in Morocco. These two stations offer a wide range of soil types. At Sidi El Aydi, draft data were collected on clay soil in June, 1987, in a field that had been chisel-plowed followed by an offset disk operation in October, 1986.

Table 1 Soil Classification, Moisture Content and Bulk Density of the Experimental Areas

Soil		Chisel-disked	Soft sand	Lentil Stubble
Sand,	%	22	77.5	39.5
Silt,	%	20	9.0	11.0
Clay,	%	58	13.5	49.5
Classification		clay	sandy loam	clay
Bulk density: (Mg/m^3)				
0-6 cm		1.54	1.56	1.55
0-12 cm		1.42	1.60	1.49
Water: (% db)				
0-6 cm		14.0	4.7	7.4
0-12 cm		23.7	2.6	7.0

Draft data were obtained at Khemis Zemamra on soft sand and a lentil stubble surface. The soft sandy field had no tillage on it for over two years. The lentil stubble field was clay soil with slight ridges resulting from the lentil rows. All tests were oriented with the rows. The draft data were obtained in October, 1987. **Table 1** illustrates the soil classification of the test areas and associated physical soil properties.

Data were recorded in three different gears with three travel speeds in each gear for each implement. At each speed and depth, 20 observations of travel speed, draft and fuel consumption were recorded.

Tillage depth was measured manually. The depth was considered to be the distance from the implement's deepest penetration to the top of the undisturbed soil surface. Five observations were made, averaged and rounded to the nearest cm.

Results

Much of the literature supports a simple linear function relating

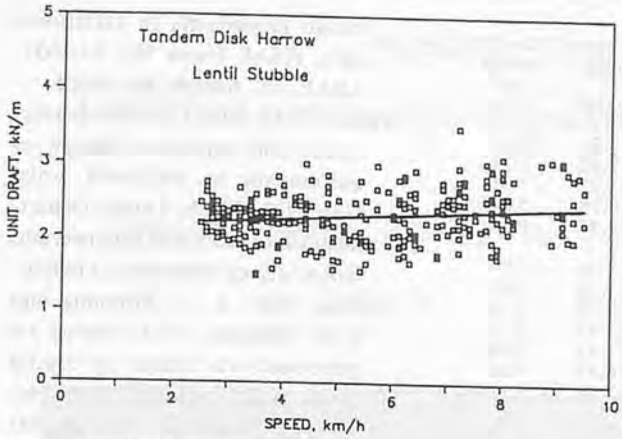

Fig. 1 Actual and predicted unit draft.

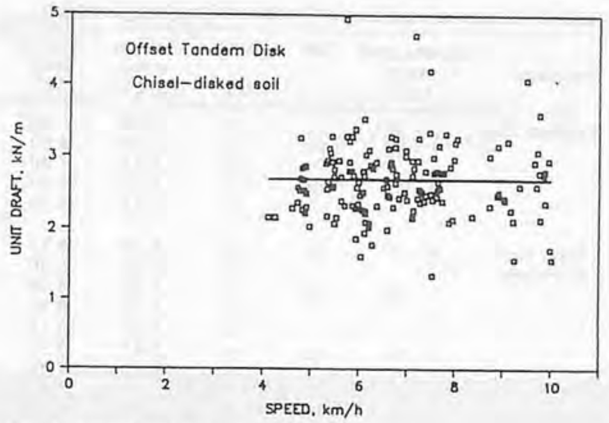

Fig. 2 Actual and predicted unit draft.

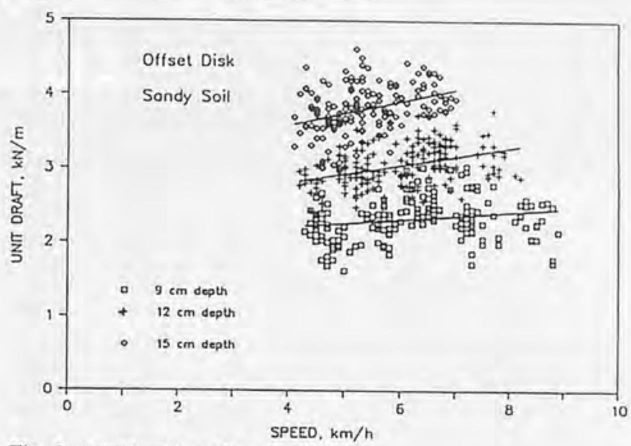

Fig. 3 Actual and predicted unit draft.

implement draft to travel speed and implement depth. Therefore, the simple linear expression:

$$Y = a + b*S + c*D \quad (1)$$

where, Y = draft per unit width or draft per toll,
a = intercept
b,c = regression coefficents
D = implement depth, cm

was chosen as the function to predict draft. Simple linear regression analysis were used to determine the coefficients a, b and c.

Figs. 1, 2 and **3** illustrate the response of implement draft to changes in travel speed and depth for the tandem disk and offset disk. For both disks, changes in speed result in very small changes in draft. The biggest changes in draft are a result of changing operating depth of the implements, **Fig. 3**.

Table 2 is a summary of the travel speed range, soil type, tillage depths, and averages of speed, draft, energy and fuel usage at each specified depth. Calculations for energy assume a field efficiency value of 80%. Because little changes in draft occur with changes in speed, averaging of the draft over the speed range at a given depth and soil was warranted for simplicity of presenting the results. Tillage operations that utilize the disk plow and offset disk will obviously require larger amounts of fuel. Certainly, implements should not be used at depths greater than required to perform the necessary tillage operation. Where usage of some implements have about the same end result, choices of one implement over another can be easily made based on the quantity of energy required for each implement.

Table 3 provides a summary of the regression coefficients in equation (1). Unit draft can be predicted with some success for all implements except for the chisel plow with sweeps on the lentil stubble, the chisel plow with points on a chisel-disked surface and the tandem disk on the chisel disked surface. The predicted values for the chisel plow are in units of N/tool and for the other implements, the predicted unit draft is in units of kN/m of width.

Conclusions

The choice of implements can result in reduced energy and fuel requirements for some tillage operations. Disk plows and offset disks have higher energy requirements and should not be used when tandem disks and sweep machines, which have lower energy requirements, could be used. Tillage operations should be chosen to keep energy requirements to a minimum.

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Table 2 Results of Implement Draft and Fuel Measurements

Implement	Ground speed range km/h	Soil	Depth cm	Average speed km/h	Average draft kN	Energy MJ/ha	Average fuel L/ha
Tandem disk	2 - 10	ls	10	5.90	6.46	27.28	5.63
	2 - 10	ss	11	5.80	4.60	19.42	5.26
			16	4.93	7.40	31.25	7.01
	1 - 11	cd	10	7.65	4.59	19.38	5.61
			13	6.33	5.79	24.45	6.58
Chisel plow w/sweeps	4 - 10	ls	10	6.35	5.52	27.91	5.00
			14	6.55	6.30	31.75	5.01
	3 - 10	ss	8	5.40	4.79	24.14	6.34
			12	4.92	8.32	41.93	7.92
			16	4.61	10.18	51.31	9.28
	1 - 9	cd	9	5.47	3.30	16.63	5.86
			16	5.10	5.46	27.52	5.91
Chisel plow w/points	2 - 8	ls	8	4.82	4.53	22.83	4.98
			10	5.84	9.37	47.23	5.69
	2 - 8	ss	12	4.94	8.09	40.78	7.89
			16	4.48	11.05	55.70	10.21
	2 - 9	cd	9	5.98	3.63	18.30	5.69
			16	4.52	4.28	21.57	8.61
Disk plow	1 - 5	cd	17	3.51	3.05	44.85	19.40
			24	2.72	10.02	147.35	29.10
Wide sweep	5 - 9	ls	6	6.37	4.92	22.52	4.87
			9	5.95	5.40	12.50	4.86
			11	5.37	6.12	28.02	5.46
	3 - 9	ss	11	5.81	7.07	32.37	6.48
			14	5.35	8.89	40.70	7.56
			16	5.40	9.44	43.22	8.69
	3 - 9	cd	8	6.36	6.85	31.36	5.77
			14	5.46	10.09	46.20	7.55
Offset disk harrow	4 - 12	ls	9	7.40	5.29	31.49	5.93
			11	6.75	8.90	52.98	6.93
	5 - 11	ss	9	6.37	6.82	40.60	8.10
			12	6.01	8.39	49.94	9.11
			15	5.35	10.28	61.19	10.22
	5 - 11	cd	11	6.83	5.54	32.98	7.28

ls = lentil stubble; ss = soft sand; cd = chisel-disked.

Table 3 Parameter Estimates of Unit Draft Equation (1)

Implement	Soil	y	Parameter estimates a	b	d	r^2
Tandem disk	ss	kN/m	− 0.88	− 0.05	− 0.20	0.79
	cd	kN/m	0.22	0.00	0.13	0.15
Chisel plow w/sweeps (9 shanks)	ls	N/t	778.28	3.99	−16.95	0.14
	ss	N/t	94.48	−20.18	72.29	0.83
	cd	N/t	111.55	− 9.11	33.89	0.63
Chisel plow w/points	ls	N/t	−649.64	38.71	130.66	0.63
	ss	N/t	−218.97	20.62	84.64	0.55
	cd	N/t	379.67	− 8.26	7.65	0.03
Disk plow	cd	kN/m	− 20.37	0.63	1.30	0.64
Sweep	ls	kN/m	0.21	0.07	0.20	0.56
	ss	kN/m	0.35	− 1.17	0.25	0.49
	cd	kN/m	− 1.52	0.35	0.24	0.53
Offset disk	ls	kN/m	− 4.16	0.02	0.66	0.61
	ss	kN/m	− 0.39	0.09	0.24	0.78

ls = lentil stubble; ss = soft sand; cd = chisel-disked.

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ABSTRACTS

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Economic Evaluation of Multicrop Threshing System in Nigeria: Joseph Enaburekhan, Lecturer, Dept. of Mech. Engg., Faculty of Technology, Bayero Univ., Kano, Nigeria.

This paper investigaes the use of multicrop threshers in threshing wheat and paddy in some mechanical farms.

The parameters investigated were the fixed and variable factors for various capacities and sources of power. The cost analysis of such threshers for various crop area and the appropriateness of the present threshing system were discussed. It was found that present threshing systems were underemployed.

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Role of women in Rural Domestic Activities and Energy Use Patterns in Hissar District—A Case Study: D.N. Sharma, Coordinator; Nishi Sethi, District Extension Specialist (Home Science); Sundershan Mehta, Asst. Prof. (Home Science), IATTE, Directorate of Extension Education, Haryana Agricultural University, Hisar 125004, India.

The household activities in rural areas is one of the most important activities from the point of view of energy and human life. The rural women life is over-burdened of labour for family maintenance. Very little attention is given to rural women relative to their active involvement in heavy duty household work. In order to generate information about the extent of involvement of the average rural women in daily household activities, a study was conducted in Hisar district in different categories of farming families.

The energy consumed to perform household activities like cooking, cleaning, animal care, fuel gathering, and miscellaneous activities by all respondents were calculated on the basis of a survey. The percentage of respondents were from the farming group 84 per cent of which having landholding size of 10 acres and above. The total energy input (KJ/household/day) from different operations on the basis of age groups were 2708.13 KJ, 2774.92 KJ and 2481.28 KJ from Group I, II and III, respectively. Maximum energy input was in age Group II. Similary, maximum total energy for various household activities is consumed by the family having landholding of 2.5 acres (3225 KJ) as compared to landholding of 5-10 acress (2795.39 KJ) followed by above 10 acres (2640.87 KJ), 2.5 to 5 acres (2359.61 KJ) and landless (1838.97 KJ). It was also observed that cooking, cleaning, fuel gathering and animal care were the primary activities in rural areas where maximum energy is consumed. In all categories of farming families, for personal care and entertainment the rural women devoted very limited or no energy. It was also observed that small to medium families devoted more energy in miscellaneous activities like knitting, embroidery and weaving. The energy consumption by the farming family was greater than the non-farming familes. This is because the farming families have more animals. Non-farming families devoted more time and energy to miscellaneous activities.

963A

Field Loss Evaluation of a Combine Harvester in Rice Crop in the Sudan—Part I: Ismail Mustafa, Agric. Engg. Administration, Ministry of Agriculture, Khartoum, Sudan; Mustafa A. Hommeida, Dept. of Agric. Engg., Univ. of Khartoum, Khartoum, Sudan.

A split-split plot experiment was conducted in Abu Gassaba Pilot Farm in Dueim District in the Sudan to evaluate the various field losses sustained by a conventional rice combine harvester. The grain moisture content and machine parameters such as the forward speed, reel speed and cylinder speed were taken as independent variables. The dependent variables were the various combine losses.

Stastical analysis showed that the decrease of the crop moisture content resulted in increases for both header and the gross losses. However, the decrease in the moisture content resulted in less threshing, walker and shoe losses. Increasing the reel index, defined as the ratio of the reel speed to the forward speed, resulted in increasing all of the combine losses. Increasing the cylinder speed resulted in the decrease of the amount of the unthreshed heads. However, it led to the increase of the walker, the shoe and the gross losses. The header loss was found to constitute the major loss (49.1%); followed by the walker loss (24.2%); shoe loss (21.4%); and the threshing loss (5.3%).

963B

Field Loss Evaluation of Combine Harvester in Rice Crop in the Sudan—Part II: Ismail Mustafa, Agric. Engg. Affaires Adm., Ministry of Agriculture, Khartoum, Sudan; Mustafa A. Hommeida, Dept. of Agric. Engg., Univ. of Khartoum, Khartoum, Sudan.

Experimental data for harvest losses of a rice combine was analysed using the analysis of variance and regressional analysis. The various combine losses were taken as the dependent variable while the crop moisture, reel index and the cylinder speed were taken as the independent variables. Four regression models were tried, namely; the linear, log, natural log and the exponential. The log model was found to give the best fit for all types of the combine losses.

The use the reel speed and forward speed, instead of the reel index, in the regression analyses gave better estimates for all types of losses.

The header loss was found to be affected most by the forward speed, crop moisture, and the reel speed. However, the gross loss was found to be affected most by the forward speed, reel speed, and moisture content.

Assuming 2.5% gross loss as the tolerable target loss, it is recommended that the rice crop in the Abu Gassaba be harvested when the crop moisture content is 15%; the reel index is 1.2; and the cylinder speed is about 22 m/s.

964

Research on Safe Storage of Moist Wheat Grains in Sealed Plastic Bags: Si Mei Qi, Instructor, Food Engg. Dept.,; Li Man, Instructor, Water Conservancy Dept. Beijing Agric. Engg. univ., Qinghua Donglu, Beijing, China

Wheat develops mould when it is harvested in the rainy season. This causes large losses in China every year. Artificial drying may reduce these losses but the drying equipment's capacity is too small to process all the harvested crop before significant losses occur. The method of sealed-bag storage for grain is an easy and feasible technique to allow short-term storage of wet wheat while it awaits drying. This paper reports on the research and test result of this technique in China. Tests in the laboratory and in the real-life situation proved that if wet wheat grains (M.C. w.b. 25%) are put into clear polythene bags (930 × 550 × 0.03mm) with a minimum of retained air and sealed for a period of eight to 10 days both the biochemical and baking quality are maintained (only the viability of wheat has some reductions) or even improved in some conditions. These bags are stored in typical farm barn conditions. This discovery is important for preventing mould losses not only in North China but also in other regions of the country.

966

Surface Coating Effect on Soil-Metal Adhesion: Azhar Iqbal Mufti, Graduate Student, AIT and Agr. Engr., FMI, P.O. NARC, Islamabad, Pakistan; G. Singh, Prof. and David Gee-Clough, Assoc. Prof., AFE Division, AIT, Bangkok, Thailand

A study was conducted to investigate the effect of different surface coatings on soil-metal adhesion. The floats were tested under controlled laboratory and quasi-static conditions in Bangkok clay soil at five soil moisture levels, i.e., 12, 19, 25, 31 and 48% (db). The friction characteristics of coating improved the scouring and reduced the drag in enamel and teflon coated floats. A reduction of 30% to 50% in drag was recorded in teflon and enamel coated floats in dry and wet soils at 14 to 31% soil moisture contents. In puddled saturated soil a reduction of 11% and 30% in drag was also observed in enamel and teflon coated floats, respectively. The overall performance of the enamel coated float was found better than teflon, zinc and mild-steel coatings at all moisture levels. Qualitative observations indicated enamel to be more resistant to abrasion than teflon and zinc.

967

Testing and Evaluation of Four-wheeled Camel Cart: N.K. Mehta, Pool Officer (C.S.I.R., New Delhi), C.T.A.E.; Pratap Singh, Prof., C.T.A.E., Udaipur, India

India has 1.7 million head of camel which are used for transportation of goods to short distances using camel drawn carts. The four-wheel cart has platform equipped with pneunatic types (5-17). The cart has a turntable for easy turning. The payload carrying capacity was 2000 kg on different terrains. The draft was maximum on loose ground surface and minimum on tarmacadam road, that also varies linearly with the pay load.

968

Scheduling the Work-Rest Cycle of Draft Buffaloes in Rotary Mode of Work: T.C. Thakur, Prof.; M.P. Singh, S.R.O.; Bhagwan Singh, Prof. and Head; D.K. Vatsa, Res. Assoc., Dept. of Farm Machinery and Power Engineering, G.B. Pant

Univ. of Agriculture and Technology, Pantnagar 263145 (U.P.), India

Studies were conducted in the scheduling of the work-rest cycle of male Murrah buffaloes while working in rotary mode at draft ranging from 70 to 145 kgf (6 to 12% of their body weight). The buffaloes were allowed to work in three cycles of 1 h work-1/2 h rest, 2 h work-1/2 rest and 2 h work-1 h rest for a total work period of four hours. all the physiological responses increased significantly with the period of work but approached closer to pre-test condition depending upon draft and environmental conditions. A fatigue score card was prepared on the basis of physiological responses in order to determind the period of rest needed for comfort of the animals. For draft up to 95 kgf (8% of body weight), 2 h work-1/2 h rest and for higher draft, 1 h work-1/2 h rest was found comfortable up to the second period of work. The power output of buffaloes decreased by about 10% up to the third period of work and, thereafter, it decreased substantially from 13 to 21% from the initial value. The optimum power output was 0.87 hp at the hitch point of animals while working at 1.98 km/h speed and developing 120 kgf (10% of their body weight) draft.

971

Effect of Polishing Rice Grain on Whiteness and By-products: Ghulam Abbas Khuhro, Director Farms; Ghulam Hyder Jamro, Asst. Prof., Dept. of Agronomy; Sheruddin Bukhari, Assoc. Prof., Farm Power and machinery, Sind Agric. Univ., Tandojam, Pakistan.

A laboratory experiment was conducted to investigate the effect of polishing on whiteness and by-products of milling of various varieties of rice. The varieties under study were IR-6, DR-82, DR-83 and Lateefy. The samples were collected from the Rice Export Corporation of Pakistan (R.E.C.P) and Bari Rice Mill Muredeke, Lahore. The tests were carried out by polishing each variety for 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 seconds. The time of polishing was the main factor to assess the rice varieties for their whiteness and by-products.

It was found that the polishing of IR-6 for 70 seconds, DR-82 and DR-83 for 80 seconds and Lateefy for 90 seconds gave disirable whiteness of 42.0, 41.5, 41.2 and 37.6, respectively. The observations on the effect of polishing of rice grain on yield of head rice recovery showed significant reduction with increase in polishing time for all the varieties, whereas the percentage of brokens and bran decreased significantly.

972

Comparative Performance of Different Water Lifting Buckets in Manually-operated Counterpoise Bucket Lift: S.C. Senapati, Agric. Engineer, Water Management Project, R.R.S., Chiplima, Sambalpur; S.D. Sharma, Prof. and Head, Dept. of Soil and Water Conservation Engg., C.A.E.T., Bhubaneswasr, India.

Manually operated counter poise water lifting devices are still used widely in rural areas in the state of Orissa, India. Three types of water lifting buckets, namely; kerosene tin, metallic bucket and earthen pot are commonly used in the counter poise water lifting devices. These buckets were tested in the field to compare the hydraulic performance as per their shape to lift water from different depths. The present study reveals that the average discharges from manually operated counter poise water lifting device using kerosene tin were 0.185, 0.176, 0.158 and 0.139×10^3 litres/min, using metallic bucket were 0.164, 0.151, 0.137 and 0.136×10^3 litres/min, using earthen pot were 0.168, 0.156, 0.143 and 0.134×10^3 litres/min at lifting heads of 1.2, 1.8, 2.2 and 2.5 meters, respectively. The performance of these three water lifting buckets were evaluated considering discharge capacity, ease of operation and overall effect of the shapes. The kerosene tin bucket gave the highest average discharge rate due to its flat bottom surface, high capacity and rigid attachment with the bamboo/rope of the counter poise over the other two types of buckets. The earthen pot bucket ranked second among the three buckets and gave more discharge than the high capacity metallic bucket owing to its parabolic bottom surface and ease of operation. It is recommended that a smooth, flat or parabolic surface with rigid attachment arrangement water lifting bucket in a counter poise water lifting device be used to lift large volume of water per unit time with less force.

973

Improved Indigenous Machinery for Vertisols in the Semi-arid Tropics: T. Guruswamy, Principal; Manoj Mathew, Asst. Prof. (Farm Machinery); G. Neelakanthayya, Junior Engineer (Agriculture), College of Agric. Engg., Raichur 584101, India.

Seventy-five percent of the cultivated area in India is under rainfed agriculture and about 45% of the total food production comes from these areas. Crop production poses a problem due to very low, ill-distributed and erratic rainfall. Among the various problems and constraints in crop production in vertisols in the semi-arid tropics, lack of suitable low cost and efficient tools and implements for different operations, particularly for the small and marginal farmers. In order to overcome these problems, the operations which require immediate attention were identified and the matching indigenous improved tools and implements developed were discussed. The use of such improved indigenous machinery not only enhanced the utilization of animal energy but also reduced the drudgery, saved operating time, conserved soil moisture, reduced runoff and soil erosion, thereby increased the infiltration, proper distribution and placement of seeds and fertilizers, suppressed weed growth and, ultimately, enhanced the yield of major dry land crops like safflower, sunflower, sorghum and cotton to nearly 9 to 15%.

975

Equilibrium Moisture Content Models for Paddy Crop for Bhubaneswar Region, Orissa: P.C. Senapati, Agric. Engineer; J.C. Paul, Post-graduate Student; A.K. Dash, Post-graduate Student; B. Panigrahi, Lecturer; S.N. Mohanty, Head, Agric. Processing and Food Engg., Orissa University of Agriculture and Technology, Bhubaneswar 751003, Orissa, India.

The weekly mean values of equilibrium moisture contents of paddy were estimated based on mean weekly temperature and relative humidity data for Bhubaneswar over a period of 25 years (1964-88). The probability analysis of mean weekly value of EMC has been incorporated in this paper for sound interpretation of EMC values. At all probability levels, i.e., 10 per cent and above, the EMC values remain above the safe moisture limit throughout the year and, therefore, it is unfavourable for grain storage in bags or other pervious structures. The harvesting months (April and October) of rabi and kharif crops have fabourable conditions for sun-drying except when there are sudden rains or cloudy weather.

989

Design and Development of Expert Systems: Energy Crop Selection—1: Mohammad Afzal, Senior Engineer, National Agricultural Research Centre, Islamabad 45500, Pakistan; Stanley J. Clark, Prof. and Head, Agric. Engg. Dept.; Wayne A. Geyer, Prof., Dept. of Forestry, Kansas State Univ., Manhattan KS 66506, U.S.A.

An expert system for the selection of energy (firewood) crops for arid and semiarid regions was developed on a Personal Computer (PC) using a commercially available expert systems development tool. It represented the available expertise adequately, and produced acceptable decisions. It handled Certainity Factors and missing or "unknown" as values for some of its parameters. It can easily be updated or modified if necessary. Consultation with this expert system requires a PC compatible computer with 512 KB RAM and two disk drives or one with a hard disk.

990

Design and Development of Expert Systems: Energy Crop Selection—2: Mohammad Afzal, Senior Engineer, National Agric. Res. Centre, Islamabad 45500, Pakistan; Stanley J. Clark, Prof. and Head, Agric. Engg. Dept. Wayne A. Geyer, Prof., Dept. of Forestry, Kansas State Univ., Manhattan, KS 66506, U.S.A.

The expert system approach was applied to the selection of fuelwood plant species for the humid tropics and tropical highlands. An expert system ECE.2 was developed on a personal computer with a commercially available low-cost shell. It contained knowledge about aggressive and fast growing energy plant species grown under the above climatic conditions. ECE.2 considered environmen tal (climatic), soil, and plant characteristics as its parameters for the knowledge base. ECE.2 utilized the backward chaining inference strategy; handled Certainty Factors, and missing parameter values. It was found capable of expert level decisions in its domain of knowledge. ECE.2 requires a PC compatible computer with a minimum of 512 KB RAM, and two disk drives or one with a hard disk.

991

An Operations Research Model for Energy Crop Evaluation: Mohammad Afzal, Senior Engineer, Farm Machinery Institute, National Agric. Res. Centre, Islamabad 45500, Pakistan; S.J. Clark, Head, Agric. Engg. Dept., Kansas State Univ., Manhattan, KS 66506, U.S.A.

A general purpose, low cost, and PC-based Linear Programming model was formulated for the evaluation of energy crops in an existing farming system. The model consisted of an objective function i.e., maximization of return; activities, and constraints. Ipil-ipil was introduced into a base case model (wheat, maize, and tractor activities) with and without the additional capital. The model analysis resulted in an increase of 15% in return with the introduction of ipil-ipil. The return was three times greater when capital was also provided in the model. This model's performance was satisfactory in evaluating farm enterprises singly or in conjunction with other new activities.

992

Heat Loss and Optimal Cost Analysis for Poultry Buildings: Dhia A. Alchalabi, Asst. Prof., Agric. Mechanization Dept., College of Agriculture, Abu Ghriab, Bhagdad, Iraq.

Condensation often occurs on windows and walls when inside surfaces are cold. Poorly insulated buildings (walls) have inside surface temperature below the dew point. Fortunately, as more insulation is placed in the wall, the inside surface temperature comes closer to house air temperature and the possibility of condensation is less.

Inside dew point temperature (D.P.T.) and wall surface temperature (W.S.T.) were used to evaluate (analyzed) heat loss and optimal cost to select the appropriate wall to design a poultry house. Three types of buildings (gable, shed, flat) were analyzed for heat loss, with or without windows. The use of computer to do this task made it even easier.

For poultry buildings in Iraq, the selected wall (from 27 types of walls) was 20 mm gypsum plaster, 240 mm thermoston, and 20 mm cement plaster. This wall will resist water condensation even to −20°C outside design temperature, and 20°C inside design temperature with 75% relative humidity. The ideal type of building, based on heat loss analysis was flat building without windows.

998

Enamel Coating Effect on Moldboard Plough Forces: Azhar Iqbal Mufti, Graduate Student, A.I.T., Bangkok and Senior Engineer, FMI, NARC, Islamabad, Pakistan; David Gee-Clough, Assoc. Prof., Div. of AFE, AIT, Bangkok, Thailand.

The performance of coated and uncoated mouldboard plough was compared under controlled laboratry conditions in Bangkok Clay soil. The tests were conducted at four moisture levels namely, 16, 21, 31 & 51% db. and three speed levels; 1, 2 & 3 km/h. The depth of cut, cutting width and lift angle were kept constant. Enamel coated plough had better scouring qualities, at all moisture and speed levels. A decrease in draft (19-22%) was observed when the speed was increased from 1-3 km/h. In wet unsaturated soils (21 and 31%), 3 to 28% reduction in plough draft was abserved at three selected speeds. Puddled saturated soil (51% m.c. db) resulted in 3 to 28% reduction in draft at three speed levels (1, 2 & 3 km/hr). At this moisture, low travel speed gave higher reduction (28%) in plough draft. A cyclic nature of the plough forces was observed.

999

Shear Force Requirement of Safflower Stem: M.M. Ghotankar, Asst. Prof., College of Agric. Engg., M.A.U., Parbhani 431402; S.H. Adhaoo, Assoc. Dean, College of Agric. Engg. and Tech., P.K.V., Akola 444104 (MS), India.

The shear force was inversely proportional to the deformation rate for three moisture levels and five stem diameters under study. The shear force for 6 mm stem diameter at 1.57 percent moisture content ranged between 66.63 and 52.00 kg, at 20 percent moisture content; 59.25 and 55.5 kg and at 42 percent moisture content; 62 and 50 kg, respectively. For stem diameter of 16 mm these values were 330 to 195 kg at 1.57 moisture content; 296 to 262 kg at 20 percent moisture content; and 287 to 236 kg at 42 percent moisture content, respectively. Similar trends were observed for all intermediate stem diameters. The shear force requirement of stems werre directly proportional to stem diameter. With the increase in moisture content of the stem, keeping stem diameter constant, the shear force decreased. The visco-elastic properties of the stem may be the reasons for such bahaviour during shear tests.

100

Operational Parameters for a Diesel Engine Run on Biogas—A review: A.N. Mathur, Princ. Sci. Officer; V.K. Vijay, Asst. Prof., Renewable Energy Centre, College of Technology and Agric. Engg. Udaipur, India; S.S. Bhatnagar, Executive (Erection and Controll), AIFA Levels, Baroda, (Gujarat), India.

Biogas, as a renewable energy source, presents remarkable potential for use in diesel engines as replacement of diesel. Work done on performance and operational parameters of diesel engine run on biogas has been reviewed and compiled in this paper. It is believed that the results of various studies presented in this paper may be useful in optimizing engine operating parameters and also provide tools to evaluate engine performance. An inference on essential modifications to be incorporated in the diesel engine and its accessories for proper and efficient operation of a biogas based dual fuel system has been outlined. ■■

EIMA — International Agricultural Machinery Manufactures Exhibition

November 6-10, 1991
Bologna, Italy

The 22nd occasion of EIMA confirms the success of the show dedicated to the mechanization of agriculture and green areas, by introducing an important innovation: the construction of a new pavilion (n. 36 in the Bologna fair neighbourhood) with a surface area of 12 000 square metres making it possible to reach a total exhibition area of 104 000 square metres.

EIMA 91 organized by UNACOMA in collaboration with the Autonomous Body for Bologna Fairs, promises to be the most important event for the Italian and foreign agricultural machinery construction industry with operators, economists and technicians from all over the world who will be offered a vast and articulated panorama of the technologies available for professional agriculture, breeding and "green" hobbies.

EIMA also promises to be a showcase of innovation with the Competition and Exhibition of "technical innovations" 1991, promoted by UNACOMA under the aegis of the Ministry of Agriculture; during the 22nd EIMA there are also plans for meetings, press conferences and conventions on the most important themes of mechanization in view of the changes in the situation of Community and world agriculture. In this connection, your attention is drawn to the fact that during EIMA 91 the third round table of the Club of Bologna will take place, this is an association of experts from all countries with advanced and emerging agriculture, which organizes the presentation of studies and surveys on various aspects of mechanization in the different geopolitical areas of the world.

Technical data:

- Bologna's Fair neighbourhood covers a total surface area of 250 000 square metres; 18 covered air-conditioned pavilions for an exhibition area of 104 000 square metres;
- airport at 6 kms, railway station and town centre at 2 kms; superhighway exit directly to the fair (No. 8); parking for 4 200 cars.

Services Available to Exhibitors and Visitors:

- Business Centre to receive foreign visitors; interpreters on hand;
- EIMA Organization Offices; Press Office; ICE Office and Foreign Ministry Office;
- Travel agencies, banks, import-export offices; specialized press area;
- Official Hotel Booking Office: SOGEPACO, Piazza Costituzione, 5/c-40128 BOLOGNA - Tel. 051/6435111 - Fax 051/6435149 - Telex 511098;
- Conference halls and meeting rooms (Palazzo Congressi, Service Centre, pad. 34);
- Refreshments: 3 restaurants/self-service and 15 coffee and snack bars within the Fairgrounds.

International Agricultural Engineering Conference

December 7-10, 1992
At Asian Institute of Technology
Bangkok, Thailand

In December 1990, an International Engineering Conference and Exhibition was held at the Asian Institute of Technology (AIT), Bangkok, Thailand. This conference attracted a wide cross-section of senior researchers, scientists, extension workers and planners from over 24 countries. The conference received an overwhelming response and was very successful.

The proposed conference aims at providing a friendly and relaxed atmosphere to encourage the interchange of ideas between peers, and provide opportunities for researchers, managers and planners to learn from each other.

The conference will be organized by the Division of Agricultural and Food Engineering in collaboration with the Agricultural Land and Water Development Program (ALWDP) of the Asian Institute of Technology, Bangkok, Thailand and be held on the AIT campus which is 42 km north of Bangkok.

Topics

Papers are invited in the following areas:

- Farm Power and Machinery
- Post-harvest Technology and Biotechnology
- Soil and Water Engineering
- Irrigation Systems Management
- Drainage Engineering
- Agro-meteorology
- Energy in Agriculture
- Agricultural Systems Engineering
- Structures and Environment
- Electronics in Agriculture
- Agricultural Waste Management
- Agro-industry
- Graduate Education in Agricultural Engineering
- Ergonomics
- Terramechanics
- Standards and Safety
- New Materials
- Emerging Technologies

Call for Papers

Abstracts in English not exceeding 500 words, should be submitted before 31st December 1991. Each abstract will be reviewed and the decision of the editorial board will be conveyed to each author by 29th February 1992. The final papers must be submitted by 31st July 1992.

Registration

Registration fees will be as follows:

Before 31st August 1992

Participant US$300.00

Accompanying person US$150.00

Deadlines to Remember

Return of Information Form 30th Sept. 1991

Receipt of Abstracts 31st Dec. 1991

Notification of Acceptance 29th Feb. 1992

Receipt of Full Papers 31st July 1992

Pre-registration 31st Aug. 1992

For further information please write to:

Dr. V.M. Salokhe
Associate Professor
Division of Agricultural and Food Engineering
Asian Institute of Technology
G.P.O. Box 2754, Bangkok 10501 Thailand Tel. 516-0110-40 Direct: 524-5479 Telex: 84276TH Fax: (66-2) 516-2126.

Jaw-Kai Wang receives 1991 Kishida International Award

Jaw-Kai Wang, P.E., director, Aquaculture Program, University of Hawaii, Honolulu, Hawaii, is the recipient of the 1991 ASAE Kishida International Award.

The award was presented by the American Society of Agricultural Engineers during the Society's International Summer Meeting, June 23-26, at the Albuquerque Convention Center, Albuquerque, New Mexico. The Kishida International Award recognizes professional efforts that improve food production, living conditions, and/or educational levels outside the USA including educational programs, product development, consultation, or technology transfer.

Wang is recognized for his outstanding contributions in the development of Agricultural Engineering in many Pacific Rim countries. His wide-ranging methods have included research projects, graduate student training, technical writing, project planning, private consulting, and government service. He has received grants and worked for such distinguished organizations as the World Bank, the Asian Development Bank, the Rockefeller Foundation, the National Science Foundation, the U.S. Agency for International Development, the U.S. Dept. of Commerce, the U.S. Dept. of Agriculture, and many local cooperatives and commercial agriculture concerns.

Wang has contributed to over 100 publications in the Areas of Aquaculture, Agricultural Mechanization, and Tropical Production Systems Planning and Evaluation.

A strong supporter and active member of ASAE, Wang recently participated in the Task Force on Emerging Technologies and is a Founder of the ASAE Foundation.

ASAE is a worldwide professional and technical organization whose members are interested in engineering knowledge and technology for agriculture, associated industries, and related resources. The Society, headquartered in St. Joseph, Michigan, includes over 10,000 members in 50 states, 10 provinces, and 110 countries.

Edward A. Hiler Elected President of A.S.A.E.

Edward A. Hiler, currently interim chancellor and also deputy chancellor for academic program planning and research for The Texas A&M University System, College Station, Texas, has been installed as president of the American Society of Agricultural Engineers (ASAE).

He assumed this position in the Society at its International Summer Meeting, June 23-26, at the Albuquerque Convention Center, Albuquerque, New Mexico. As president of the Society, he is primary spokesperson for over 10,000 members in 50 states, 10 provinces, and 110 countries. He will hold the position of president for one year, then continues on the Executive Committee one year as past president.

Active in ASAE since 1965, Hiler served on the former Administrative Council and was director of the former Education and Research Department. He was chair of the Forward Planning Committee, has served on the ASAE Foundation Board of Trustees, and chaired the Silver Key II Fund Raising Campaign.

Hiler has been recognized by his peers, and is the recipient of many educational and research awards. His most recent award was received during the Albuquerque meeting in which he received the prestigious John Deere Gold Medal in honor of his distinguished record of engineering achievements in research, education, and administration. Hiler has also received the Award in Excellence for Team Research and the Award in Excellence for Administration from The Texas A&M University System in 1989.

Douglas L. Bosworth Elected President-elect of A.S.A.E.

Douglas L. Bosworth, P.E., manager of engineering test and reliability at John Deere Harvester Works in East Moline, Illinois, has been named President-elect of the American Society of Agricultural Engineers (ASAE). ■■

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S Kathirkamathamby


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C Rojanassaroj


G Singh


Y Pinar


A P Kaloyanov


H Have


G Pellizzi


A A Wanders


J Kilgour

BACK ISSUES

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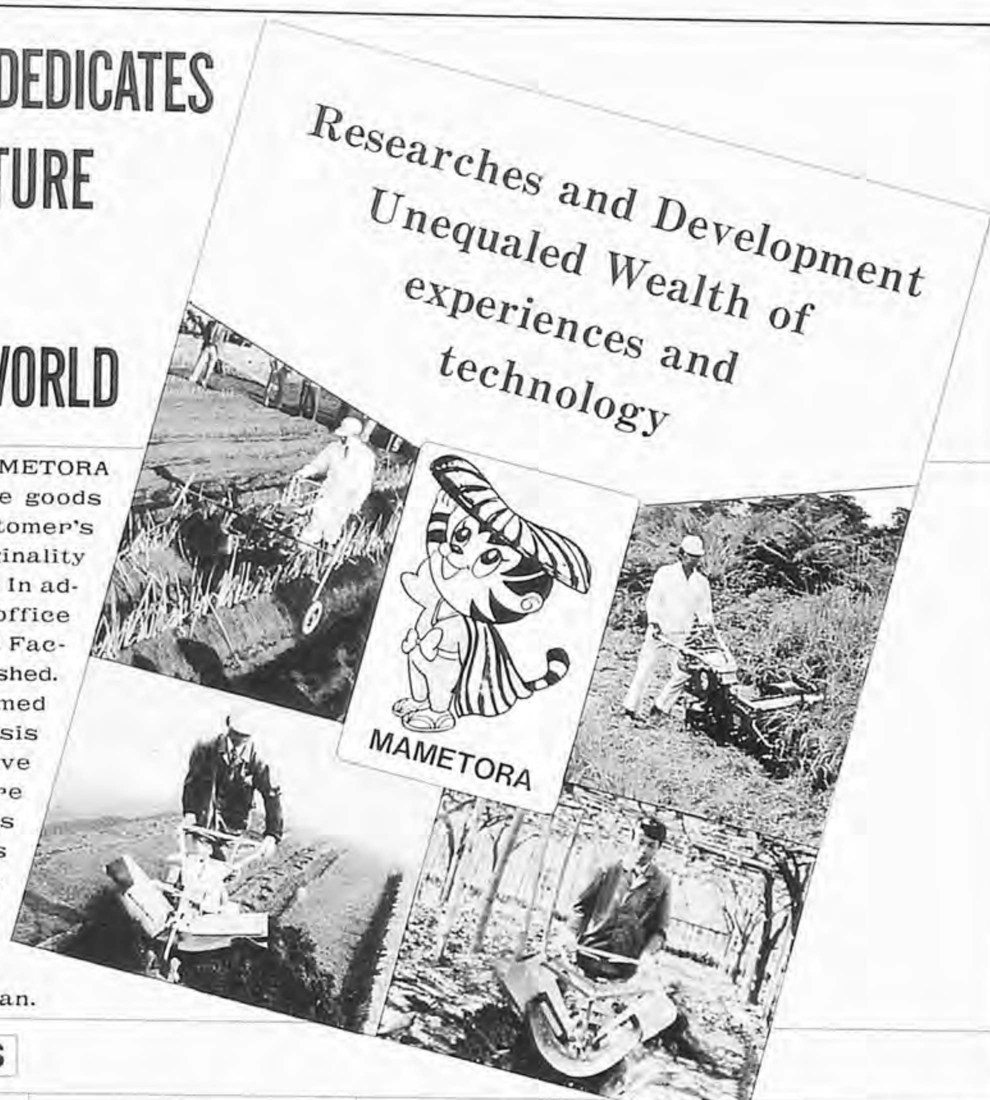
■■

MAMETORA DEDICATES TO AGRICULTURE ALL OVER THE WORLD



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