International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.40, No.2, SPRING 2009

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

International specialized medium for agricultural mechanization in developing countries

ISSN 0084-5841

AMA

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

VOL.40, No.2, SPRING 2009

Edited by

YOSHISUKE KISHIDA

Published quarterly by

Farm Machinery Industrial Research Corp.

in cooperation with

The Shin-Norinsha Co., Ltd.

and

The International Farm Mechanization Research Service

TOKYO

ADVERTISING
(Tel.+81-(0)3-3291-3672)
Yoshito Nakajima, Manager (Head Office)
Advertising Rate: 300 thousand yen per page

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

SHIN-NORIN Building
7-22, 2-chome, Kanda Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Printed in Japan

This is the 139th issue since its maiden isue in the Spring of 1971

EDITORIAL

The world population was 6.59 billion in 2006 according to the UN World Population Prospects (2006 revision) and is estimated to grow to 7 billion in several years. It projects that the world population will expand to 7.29 billion in 2015, 8.01 billion in 2025 and 9.19 billion in 2050, respectively. It has been said among specialists that the maximum population the earth can allow sustainable inhabitance is 7 billion, to which global population is projected to reach before 2015. The total cultivated land area of the world was 1.421 billion hectares in 2005 and there is no prospect of its increase. The average world population per one hectare of cultivated land is greatly increasing.

The farming population accounts for about 40.3 % of the total world population according to 2005 FAO statistics. The ratio of farming population is the highest in China, 63.7 %, and lowest in England, 1.6 %. On a global basis, the ratio of farming population has been declining, resulting from increasing shift of population from rural areas to urban areas.

All of these things clearly suggest the task of agricultural machinery experts. First of all, good use must be made of the limited cultivated land through further introduction of effective agricultural production technology or new mechanization technology to raise land productivity. At the same time, rapidly declining farming population urges us to take measures to raise labor productivity. How to do effective farming with less manpower is one of the keys in raising the productivity. With a farming population of only 1.9 %, the United States has been successful in keeping labor productivity high enough to allow the export of their farm products worldwide. This identifies the importance of raising labor productivity as well as land productivity.

Secondly, a sustainable agricultural production system must be set into operation worldwide to supply good food with reasonable price without damaging natural resources and environments. In return for economic growth, global warming is getting more serious and even violent climatic changes have occurred. Under these environmental changes, more timely operations are required and only mechanization can successfully manage the timely farm work.

In the face of the recession of the global economy with financial crisis as a start, we are obliged to know that the world economy has been supported by excessive consumption in urban areas. In this sense, the current economic crisis gives us a good chance to reconsider our way of living that will allow us a sustainable and secured life in the future. Based on what is really essential to our life, a new consumption and economic structure must be established. Japan, with only 40 % of food self-sufficient rate, depends upon three times larger farm land in other countries than domestic farm land while throwing away 19 million tons of garbage annually due to excessive food consumption. Too much eating has also caused medical problems such as metabolic syndrome and is raising medical cost. We need to improve our eating habits, to eat proper amounts of food of good quality and not to overeat. The latest state of the global economy suggests that we should change our consuming attitude. Without this change, there will be more pressure on the global eco-system with increasing population and our sustainable life will be very critical. I hope all agricultural machinery experts will play key roles in challenging new tasks for our well-being.

Yoshisuke Kishida
Chief Editor

July, 2009

CONTENTS

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

Vol.40, No.2, September 2009

Design and Performance Evaluation of a Small Tractor-Simulator

by
Indra Mani
Senior Scientist
Division of Agricultural Engineering,
Indian Agricultural Research Institute,
New Delhi - 110 012
INDIA
maniindra98@yahoo.com

J. S. Panwar
Senior Scientist
Division of Agricultural Engineering,
Indian Agricultural Research Institute,
New Delhi - 110 012
INDIA

Abstract

In India, more than 76.4 % small and marginal farmers need an intermediate power source between draught animal power and big commercial tractors, capable of developing draft equivalent to three good pairs of bullocks. A half chassis simulator of a small tractor was designed and fabricated with provision to vary pertinent chassis design parameters, e.g. wheel size, wheel base, normal load, weight distribution on rear and front wheels and thus, center of gravity of the simulator system. The system was test evaluated for tractive performance with respect to varying levels of device parameters as mentioned above and operational parameters like slip and forward speed. Based on the results of the study, a normal load level of 530 kg with a wheel base of 1415 mm (wheel I: 8.00-18.00); and 530 kg normal load with a wheel base of 1345-1415 mm (wheel II: 7.5-16.0) could be selected. Wheel III (6.00-12.00) showed aberration from the expected trends however a normal load of 230 kg and wheel base of 1305 mm could be chosen as final chassis design values for this wheel.

Introduction

A larger number of Indian farmers need a 4-wheeled power unit of 10-12 kW capable of multifarious usage on small farms with economically affordable initial and maintenance cost. Some models of these tractors are popular in Japan, China, Korea, Thailand and some other south Asian countries. In India, endeavors, in this regard, were made by some tractor manufacturing companies but, for want of proper design and also due to sufficiently high cost, small tractors could not be popularized among the farmers. They were relatively in high hp. The common flaw with these models appears to be mismatched combination of drive tyre size, chassis design, normal weight and engine application. The mathematical relationship for design of a tractive system was given by Gill and Vanden Berg (1966):

P = f (S, D, W, J) ....(1)

where;

P = pull
S = soil factors
D = device factors
W = weight factors
J = relative movement, expressed as actual movement for non-rolling device and slip for rolling device.

Within control limits, a designer has check over factor D and W in the context of the present study and equation (1) could be expressed as:

where;

P = f (S, d, b, wb, x − y, s)
d = dia of wheel
b = width of wheel
wb = wheel base
x – y = location of center of gravity
s = slip
S = soil factor e.g. compactness level.

The desirable aim was to create an improved design of a small tractor that was more adoptable to our conditions and suitable to economic condition of small farmers.

Thus, a study was undertaken to determine design parameters of a small tractor with the following specific objectives:

a. To design and fabricate a half chassis simulator of a small tractor to study wheel and chassis design parameters.
b. To test and evaluate the tractive performance of the simulator to optimize design parameters.

Materials and Methods

To simulate design of a small tractor and evaluate its performance in the soil bin, a structure was designed resembling to a tractor that should have:

- Characteristics of a tractor and be easily handled in a soil bin with safety.
- Provisions to vary all pertinent design and operational variables.

- Facility to mount necessary instrumentation and data acquisition system.
- Have a compact drive train and suitable power source.

The heart of this system is a traction unit called chassis simulator. It resembles a vertically cut half - section of a tractor with a provision to mount rear and front wheels, a platform for ballasting rear wheels and distribution of weight on rear and front wheels. It also has arrangement to vary wheel base and to mount pull and torque transducers and a safe power supply system beside the operator's seat and instrumentation box, **Fig. 1**.

The rear wheels of three different load carrying capacities and/tyre geometry (800-18, 7.5-16, 6-12) were mounted on a 50.8 mm dia axle of 457 mm length. This axle was machined with a square hole (31.5 × 31.5 mm) at one end and a conical shape at the other end resting on a revolving center to facilitate easy removal and mounting of wheels. A sturdy autoriksaw wheel (4.00-8) with 460 mm dia and 100 mm width was used as the front wheel. The front wheel could be shifted back and forth in the longitudinal direction to get different levels of wheel base as the rear wheel was in a fixed position.

Forward travel of the half chassis simulator was provided with the help of an endless rope and winch system powered by a three phase electric motor. An independent rotational speed drive was provided to the traction wheel through a combination of different sizes of chain and sprockets, **Fig. 1**. The chain and sprockets were designed considering the expected total torque. A 19.05 mm pitch sprocket and a matching simplex roller chain were used. Using different sprocket sizes and adjusting with forward speed of the simulator, four different levels of slip were obtained. An on-line torque meter was mounted to measure input power to the rear wheel.

Result and Discussion

The parameters of tractive performance of the half chassis tractor simulator using the three test wheels were evaluated in terms of the maximum tractive efficiency, drawbar pull and the coefficient of traction. The net tractive pull was calculated corresponding to the maximum tractive efficiency and measured experimentally at different levels of slip along with the maximum drawbar pull developed by each wheel size. This was compared with the calculated net pull corresponding to maximum tractive efficiency.

Maximum Tractive Efficiency and Corresponding Slip

The maximum tractive efficiency was determined by the values of four parameters namely, pull, actual forward speed, axle torque and the angle of rotation of the wheel. Thus, the maximum tractive efficiency was not necessarily corresponding to the point of maximum drawbar pull generated by the individual wheel.

In all of the combinations of wheel size and normal load, the simulator was test evaluated in an indoor soil bin at a fixed moisture content of 12 % and three different soil compaction levels of 1.23, 1.33 and 1.44 gm/cm^3. Three wheel sizes of 8.00-18 (wheel I), 7.5-16 (wheel II) and 6.00-12 (wheel III) were used to design three different power capacity tractors. The test were conducted at four slip levels of 13, 19, 26 and 33 %, each at three wheel base dimensions of 1345 mm, 1445 mm and 1475 mm for wheels I and II; and 1305 mm, 1345 mm and 1415 mm for wheel III. Three different normal loads of 430 kg, 480 kg and 530 kg for wheel I and II and 230 kg, 280 kg, and 330 kg for wheel III were applied on rear wheels during test runs at a constant forward speed of 1.2 km/h. Pull and torque were measured for each experiment. To compare the influence of different design and operational variables on the tractive performance of the simulator, net pull, weight transfer, coefficient of traction and tractive efficiency were determined for each combination of the study

Fig. 1 Simulator of small tractor

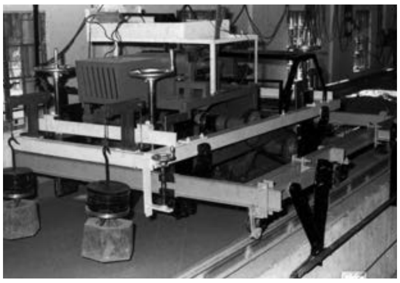


Table 1 Specifications of hydraulic cylinders fitted in feed block formation machne

Parameters	Wheel I			Wheel II			Wheel III		
	Load, kg			Load, kg			Load, kg		
	430	480	530	430	480	530	430	480	530
Maximum drawbar pull, kg	210.0 (33 %)	235.6 (33 %)	254.5 (33 %)	191.3 (33 %)	210.0 (33 %)	236.2 (33 %)	126.7 (19 %)	136.7 (19 %)	152.2 (26 %)
Maximum T.E. & corres. slip	59.05 (19 %)	60.36 (19 %)	79.09 (13 %)	69.65 (19 %)	64.93 (19 %)	68.84 (19 %)	60.74 (19 %)	58.24 (19 %)	59.06 (19 %)
Net tractive force corresp. to 2, kg	156.7	174.5	151.2	177.8	223.3	140.0	124.5	135.1	126.7
Ratio of 3/1	0.74	0.74	0.59	0.92	1.06	0.59	0.98	0.98	0.83
Maximum COT	0.43 (33 %)	0.43 (33 %)	0.42 (33 %)	0.40 (33 %)	0.40 (33 %)	0.40 (33 %)	0.50 (19 %)	0.44 (19 %)	0.43 (26 %)

variables. The pattern of influence was verified statistically also. The maximum tractive efficiency was obtained corresponding to the 19 % level of slip except for the wheel I at a normal load of 530 kg and wheel II at a normal load of 480 kg where it was maximum at a slip of 13 %, **Table 1**. Tractive efficiency of wheel I, II and III were 79, 69 and 60 % respectively, corresponding to normal loads of 530 kg, 430 kg and 230 kg. While, wheel II and III caused maximum efficiency corresponding to their minimum level of normal load, the tractive efficiency of wheel I was maximum at its maximum normal load, **Table 1**. The difference among the tractive efficiency for all the wheels, due to different normal loads was relatively small in magnitude except for wheel I at the normal load of 530 kg. The tractive efficiency averaged over the entire range of the normal loads for wheel I, wheel II and wheel III were 66.13, 67.8 and 59.28, respectively, mainly occurring at 19 %. Thus, wheel I and wheel II showed higher tractive efficiency by about 8 % compared to wheel III.

Maximum Draw Bar Pull

The maximum draw bar pull was a function of the wheel size and normal load within the configuration of the simulator tractor. For wheel I and II it occurred corresponding to the slip of 33 % at the levels of normal loads. For wheel III, the maximum pull was developed at 19 % slip due to a normal load of 230 and 280 kg and at 26 % slip due to 330 kg normal load, **Table 1**. A maximum drawbar pull range of 210-254.4 kg for wheel I, 191.3-236.2 kg for wheel II and 126.7 to 152.2 kg for wheel III were observed during the experiments. Overall maximum drawbar pull capacity for all the three wheels occurred at the maximum normal load of 530 kg, 530 kg and 330 kg with respective drawbar pull of 254.4, 236.2 and 152.2 kilograms, **Table 1**. The better tractive ability of the large dimension wheel was due to larger size and, hence, more contact area and scope of more tire deflection at the same normal load levels.

Net Tractive Pull Corresponding to Maximum Tractive Efficiency

The values of net pull, calculated from the maximum tractive efficiency, was consistently the highest corresponding to the normal load of 480 kg for wheel I and II and 280 kg for wheel III. The ratios of net tractive pull to the maximum drawbar pull were 0.74, 0.74 and 0.59 for wheel I and 0.92, 0.96 and 0.59 for wheel II at the normal load of 430, 480 and 430 kg, respectively. The same ratio for wheel III was 0.98, 0.98 and 0.83 at the normal load of 230, 280 and 330 kg, respectively **Table 1**. Thus, wheel II and wheel III had a closer agreement between the maximum drawbar pull and net pull. It could be seen that while, wheel I generated higher maximum drawbar pull compared to wheel II, the net drawbar pull generated by wheel II corresponding to maximum tractive efficiency was substantially higher than the net pull generated by wheel I. This was due to wheel II experiencing lower energy losses than the former.

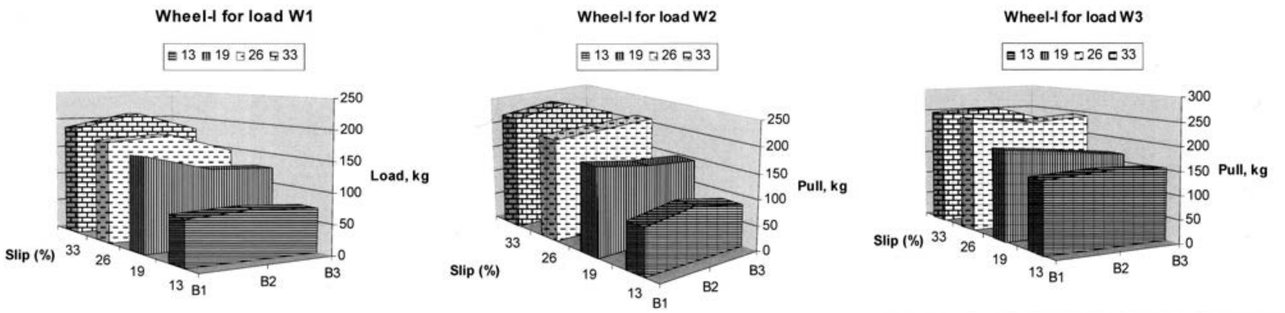
Maximum Coefficient of Traction

The maximum coefficient of traction for wheel I and II ranged from 0.40 to 0.43 and occurred at a slip of 33 %. For wheel III the maximum coefficient of traction ranged from 0.43 to 0.50 and occurred at slip levels of 19 and 26 %. Being the ratio of pull to dynamic load on traction wheel the COT had a similar trend to the maximum drawbar pull in respect of wheel slip. Thus, the three different wheels had different drawbar pull capacity, maximum tractive efficiency, net drawbar pull and coefficient of traction. Therefore, for the purpose of selection of design values for a small tractor, a good range of tractive performance variables was available depending

Table 2 Recommended design values for small tractor

Wheel size	Wheel base, mm	Normal load, kg		Average pull, kg	Drawbar power, kW	Brake power, kW
		Rear	Front			
Wheel I	1415	1060	520	400	7.00	11.6
Wheel II	1345-1415	1060	520	360	6.34	10.0
Wheel III	1305	460	220	200	1.91	3.54

Fig. 2 Interaction of slip, normal load and pull at different wheelbase (Wheel-I)



Wheelbase: B1 = 1345 mm, B2 = 1415 mm, B3 = 1475 mm on the intended power capacity of the small tractor.

Interaction of Slip, Wheel Base and Pull

The wheel base was investigated for pull at different normal loads and weight transfer at different levels of pull, slip and normal loads. The wheel base influenced pull capacity mainly through changes in weight transfer at different loads, slip and pull level. Consistently, the pull was more on the wheel base of 1345 mm or 1415 mm and compared to the pull developed with a wheel base of 1445 mm for a constant normal load for wheel I and wheel II, **Figs. 2** and **3**. For any wheel base the pull increased with increase in normal load for all the three wheels. The increase in pull with increase in normal load, for the three wheel bases tended to be maximum at 13 % and 26 % for wheel I and II, **Figs. 1** and **2**. For wheel III, the increase in pull with normal load was maximum corresponding to the slip levels of 19 and 33 % (Mani, 1995). Based on the pull developed corresponding to the 1475 mm for wheel I and II, this base length was excluded from the final selection of design values, **Figs. 2** and **3**. Wheel III did not show any appreciable difference in pull at the three wheel bases of 1305, 1345 and 1415 mm.

Final Selection of Design Values

Based on the overall performance results, the following final design values for half chassis simulator could be selected. For small tractor simulator fitted with:

1. Wheel I; a normal load of 530 kg on rear wheel, 260 kg on front wheel and a wheel base of 1415 mm was optimum.
2. Wheel II; a normal load of 530 kg on rear wheel, 260 kg on front wheel and a wheel base of 1345-1415 mm was optimum.
3. Wheel III; optimum wheelbase and normal load were 1305 mm and 230 kg, respectively.

Based on the principle of symmetry the design values could be converted suitability to obtain design parameters of a full chassis configuration of small tractor with regard to normal load on front and rear wheels, wheelbase and intended brake power. The brake power could be calculated based on the expected pull at optimum slip level of around 19 %, average tractive efficiency of 60-70 % and a transmission efficiency of 90 %. A forward speed level of 6.5 km/h for wheel I and II and 3.5 km/h for wheel III were taken into consideration for calculating brake horsepower. The design values for three different power capacity small tractors are included in **Table 2**.

Conclusions

A large size wheel could develop higher maximum pull. A maximum drawbar pull range of 210-254.4 kg for wheel I, 191.3-236.2 kg for wheel II and 126.7 to 152.2 kg for wheel III were observed during the test.

- Wheel II and wheel III had a closer agreement between the maximum drawbar pull and net pull.
- The three wheels could be treated separately as the available option for incorporation into the tractor. Thus, designs of three different power capacity tractors could be evolved.
- For a given combination level of normal load and slip, both the wheel base of 1345 and 1415 mm for the larger wheels caused quite comparable and almost equally acceptable drawbar pull as did all the three wheel bases of 1305, 1345 and 1415 wheel III.
- The final design values for three different capacity small tractors are included in **Table 2**.

REFERENCES

Anonymous. 1985. Tractor Industry in India, Research consultancy Bureau, New Delhi Vol I.

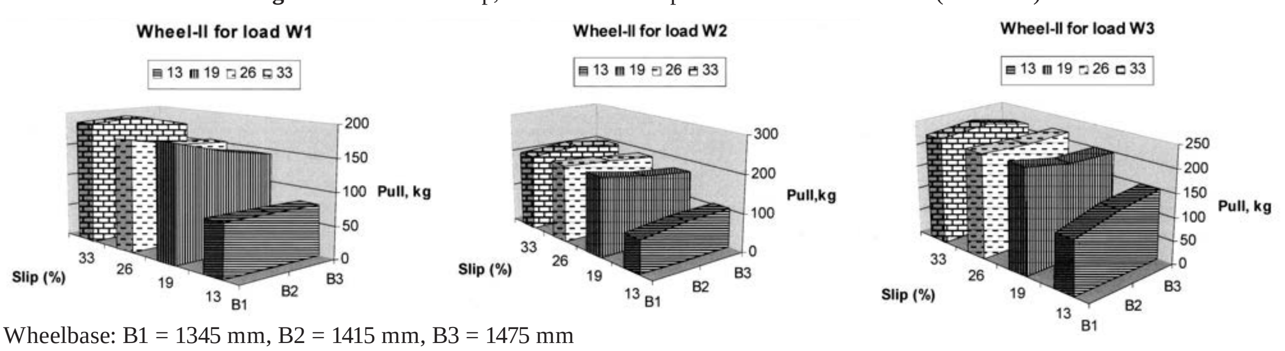
Anonymous. 1990. Popularising small tractors, Kisan Vikas Sahyog. Rastriya Kisan Sangthan Vol 10; 8-9

Anonymous. 1991. Tractor performance, Ministry of Agriculture and Cooperation, Govt. of India.

Mani, Indra. 1995. Determination of design parameters of small tractor. Unpublished Ph. D. Thesis, P.G. School, I.A.R.I; New Delhi, India.

■■

Fig. 3 Interaction of slip, normal load and pull at different wheelbase (Wheel-II)



Wheelbase: B1 = 1345 mm, B2 = 1415 mm, B3 = 1475 mm

Farm Power Status and Its Utilization Pattern in Nalanda District of Bihar - A Case Study

by

V. B. Shambhu
Scientist
Central research Institute
for Jute and Allied Fibbers,
Barrackpore-700 120
Kolkata, West Bengal
INDIA
E-mail: vbs9605@yahoo.co.in

J. P. Gupta
Dean,
Faculty of Agricultural Engineering,
B. C. K. V., Mohanpur,
Nadia-741 252 (W.B.)
INDIA

S. K. Jha
Scientist
Central research Institute
for Jute and Allied Fibbers,
Barrackpore-700 120
Kolkata, West Bengal
INDIA

Sanjay Kumar
Collage of Agricultural Engineering,
R.A.U., Pusa- 848 125
Bihar
INDIA

Abstract

This study is based on a survey of 95 farmers in Nalanda district of Bihar and was conducted through personal interviews of the farmers. The aim of study was to analyse the availability, demand/requirement and utilization of various sources of power for different farm operations and to project the future requirements of farm mechanization in Nalanda District. Maximum human power was available from small farm categories (6,980 h/ha), maximum animal power was available from marginal farm categories (1158 h/ha), maximum tractor power was available from large farm categories (171.35 h/ha) and maximum stationary engine/electric motor power was available from small farm categories (819 h/ha). Peak demand for human power requirement was in January for all farm categories and in November for marginal, small and medium size farm categories for sowing rabi and potato crops. Maximum deficit of animal power was in November (106 h/ha). Large farm categories faced a deficit of animal power requirement in most of the months. Peak demand for tractor power requirement was in the months of March, May and November for all farm categories. Marginal, small and medium size farm categories faced a deficit of tractor power requirement in most of the months. Peak demand of stationary diesel/electric motor power requirement was in the month of April for all farm categories.

Introduction

Bihar has one of India's most fertile tracts of land and nearly three-fourths of its population depends on agriculture for survival. Bihar is mainly an agricultural state and agriculture has been the main occupation of the rural people. Human power has been predominantly used for all farm operations even though wider job opportunity in the urban areas has set a trend with rural youth preferring to take a profession other than agriculture.

Farm mechanization in the state grew slowly and accelerated recently due to increased need of timely completion of field operations, better utilization of costly inputs, need to handle large volume of agro produce and improved quality of work. Availability of adequate farm power has been, thus, a critical input that determined the quality and pace of mechanization of agriculture.

Power source is one of great importance in determining the level of mechanization and agricultural development in any country. Experience has shown that an acute shortage of power exists for tillage, transplanting and other cultural operations/practices in the early period of monsoon. Further, the introduction of high yielding varieties of rice and wheat in India in the mid-sixties and their progressive expansion has increased the demand for commercial energy inputs. These varieties were more sensitive to timeliness of operations and required better crop care. Hence, the availability of adequate farm power to achieve timeliness of operations is the most important consideration for higher productivity. Sometimes, even the larger doses of fertilizers, better irrigation facilities and plant protection treatments may prove ineffective if these operations as well as other operations such as sowing, weeding and harvesting are not performed within the desired period.

The successful cultivation of high-yielding varieties also require better soil moisture and nutrient supply. Thus, more investments on commercial energy for expanding lift irrigation systems coupled with the supply of large quantities of fertilizers, insecticides and pesticides and herbicides were essential to take full advantage of the yield potential of those varieties.

Srivastava (1985) reported on the energy required for different field operations using animal and tractor power and availability of power and work output for crop production. The KW work done by using animal power was about 4.75 times that of tractor power. Thus, in terms of work output, the contribution of animals as compared to tractor power was much more.

Land Utilization Pattern of the Nalanda District (Project Area)

Land utilization pattern of the study area as obtained from official records of district and block office of respective blocks have been presented in **Table 1**. The table indicates that the geographical area of the Nalanda district and the selected blocks of Ekangarsarai, Sarmera and Rajgir was 233,906 ha, 19,744 ha, 13,546 ha, and 386,840 ha, respectively. Out of the total geographical area of the district and blocks, net sown area in the district and selected blocks was 176,686 ha, 14,327 ha, 11,846 ha, and 24,327 ha, respectively. Percentage representation of different crops grown in the study area has also been presented in the **Table 1**. Paddy occupied the largest area followed by wheat and pulse crops.

Methodology

The study was carried out in an alluvial plain zone of south Bihar in Nalanda district. The Nalanda district, carved out from the original district of Patna, was established on November 9, 1972. It is located between 24º57' to 25º27' north latitude and 85º10' to 85º56' east longitude. The total geographical area of the district is 2,367 Sq. km. The district receives 943.5 mm average annual rainfall. The total net sown area is 176,686 ha. The total net irrigated area is 134,000 ha. The cropping intensity of the district is 157.98. The major crops grown are paddy, wheat, and pulse, potato, onion and others cereals.

A three stage simple random sampling mechanism was adopted to select a village. This statistical selection procedure was comprised of blocks as the first stage sampling unit, village within the selected blocks as the second stage and the farmers within the village as the third stage sampling unit. The farmers were classified in to four categories, viz marginal farmers (MF) with less than 2 ha, small farmers (SF) with 2 to 4 ha, medium size farmers (MSF) with 4 to 10 ha, and large farmers with more than 10 ha of land. Data collection was done on the basis of a pre-designed pretested questionnaire. The information included various details of the village like farm holding, livestock population, land utilization pattern, irrigation structure, crop rotation, inventory of farm machinery and power sources. The schedule of farm operation activities carried out by the different categories of farmers was monitored to analyse the utilization of different farm power sources in the crop production. The monthly, operation-wise availability of various power sources along with their demand and deficit was determined for different farm categories in the district. The annual availability of human and animal power sources was computed by assuming that the human and animals were available for work for six hours a day and six days a week for the completed year. The annual availability of commercial power sources like tractors, diesel engines and electric motors was worked out by assuming uniform usage through out the year.

Farm power demand from different sources of farm power was computed on the basis of power requirement for different operations in specified period as recommended by University/Institutions. Farmers were consulted to know the actual power requirements for different farm operations.

Table 1 Land utilization pattern of the study area

Area/ Crop area (%)	Ekangarsarai block	Sarmera block	Rajgir block	Nalanda District
Total area (ha)	19,744	13,546	386,840	233,906
Net area sown (ha)	14,327	11,846	24,327	176,686
Paddy (%)	74.80	50.62	60.35	65.01
Wheat (%)	35.76	27.83	44.12	54.30
Pulse (%)	12.50	46.42	15.67	18.43
Onion (%)	5.40	7.72	12.38	5.82
Potato (%)	6.78	4.43	4.57	7.35
Others (%)	5.38	4.10	4.85	5.21

Result and Discussion

Status of Utilization, Availability and Demand of Farm Power Sources

Information regarding availability, utilization and demand of farm power sources of the selected farmers in Nalanda district were collected. The annual projected availability and actual demand of human, animal, tractor and stationery source of power have been presented below.

Availability and Demand of Human Power

The monthly availability of human power and its demand in different months of the year for major crops grown under different categories are presented in **Table 2**. Peak demand of human power requirement in January for all farm categories ranged between 1,967 to 2,058 h/ha. This may have been due to the combined demand of post harvest operations of paddy processing and the pre-harvest operations of onion and wheat. Human labour is demanded for field preparation, transplanting and irrigation. Simultaneously, wheat cultivation is also done which demands labour for irrigation, fertilization application, insecticide and pesticide application.

A deficit of human power was in the months of January, February, March, July and November for all categories of farmers (**Fig. 1**). The deficit of human power in January was due to transplanting and in February was due to interculturing in onion for all farm categories. The deficit of human power in July was due to land preparation and transplanting of paddy for all cat-

Table 2 Human power availability and demand (h/ha), month wise, in nalanda district

Month	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def
January	1,772	2,058	-286	1705	2,042	-337	1,612	1984	-372	1,619	1,967	-348
February	989	1183	-194	968	1,186	-218	881	1130	-254	834	1,095	-261
March	494	515	-21	486	532	-46	465	523	-58	468	521	-53
April	481	384	97	498	397	101	483	418	65	474	406	68
May	472	400	72	493	395	98	476	387	89	465	382	83
June	124	88	36	154	72	82	106	56	50	70	32	38
July	471	536	-65	437	532	-95	335	421	-86	346	405	-59
August	397	178	219	401	165	236	388	137	251	374	129	245
September	312	127	185	326	133	193	294	106	188	251	98	193
October	353	160	193	362	167	195	356	132	224	345	124	218
November	586	833	-247	584	836	-252	530	728	-198	463	645	-182
December	524	430	94	566	438	128	492	365	127	438	342	96
Total	6,975	6,892	83	6,980	6,895	85	6,413	6,387	26	6,184	6,146	38

Fig. 1 Peak human power availability and demand in nalanda district

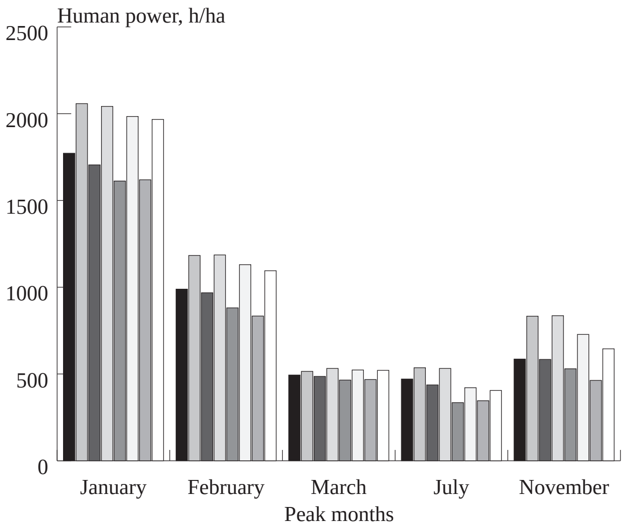
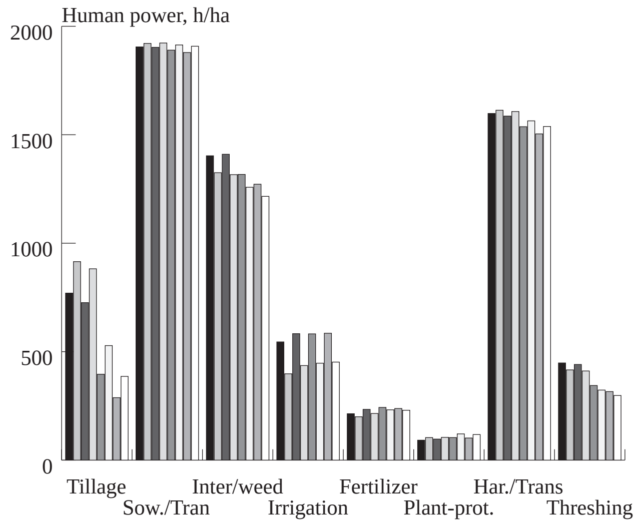


Fig. 2 Operation-wise human power availability and demand in nalanda district



egories of farmers. A deficit of human power in November was due to coincidence of harvesting kharif and sowing rabi and potato crops. In November more human power deficit was observed among marginal and small farmers (ranging between 247 and 252 h/ha) as compared to medium size and large farmers (ranging between 182 and 198 h/ha.). Higher value of deficit among marginal and small farmers was due to the fact that they depended more on bullock power as compared to medium and large size farmers who depended more on tractor power. Use of bullock power for rabi sowing and potato planting consumed more human power as compared to tractor power.

Among the different crops grown by the farmers (paddy, wheat, pulses, onion, and potato) maximum demand of human power was in the month of January for transplanting onion. Among different farm categories, it varied between 1,967 to 2,058 h/ha and the minimum in June varied from 88 to 32 h/ha. This was due to the reason stated above and in the month of June no farm operations were taken except sowing of paddy for seedlings.

Area covered by different crops, as sown in **Table 1**, shows that area covered by onion cropping is only 10 per cent of rabi cropping. If area covered by onion cropping is omitted, then **Table 2** would be modified and January and February would no longer remain months of highest human power demand. In such a case, November becomes, the month of highest human power demand. This is due to the large area of rabi and potato cultivation and to paddy harvesting. This study also shows that farmers desire to increase area of onion cropping which is more profitable, but are not able to do so because of non-availability of human power as evident from **Table 2**.

Operation Wise Human Power Availability and Demand

Table 3 shows that no deficit of human power was observed for all

Table 3 Human power availability and demand (h/ha) in nalanda district - under different farm operation

Operation	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def
Tillage	770	915	-145	726	882	-156	396	528	-132	288	386	-98
Sow./Tran	1,905	1,921	-16	1,903	1,923	-20	1,890	1,914	-24	1,879	1,908	-29
Inter/weed	1,403	1,325	78	1,410	1,316	94	1,317	1,258	59	1,272	1,216	56
Irrigation	545	398	147	583	436	147	582	447	135	585	452	133
Fertilizer	214	200	14	234	215	19	243	232	11	238	230	18
Plant-prot.	92	104	-12	97	105	-8	104	121	-17	102	118	-16
Har./Trans	1,598	1613	-15	1,586	1,607	-21	1537	1,564	-27	1,504	1,538	-34
Threshing	448	416	32	441	411	30	344	323	21	316	298	18
Total	6,975	6,892	83	6,980	6,895	85	6,413	6,387	26	6,184	6,146	38

Table 4 Animal power availability and demand (h/ha) - month wise in nalanda district

Month	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def
January	126	200	-74	124	212	-88	68	92	-24	36	48	-12
February	0	0	0	0	0	0	0	0	0	0	0	0
March	141	136	5	149	146	3	82	80	2	64	72	-8
April	84	72	12	86	72	14	77	76	1	0	0	0
May	72	68	4	81	76	5	0	0	0	0	0	0
June	78	72	6	72	64	8	58	46	12	37	24	13
July	114	160	-46	104	156	-52	86	128	-42	28	32	-4
August	96	82	14	98	78	20	72	74	-2	0	0	0
September	76	64	12	78	72	6	62	48	14	0	0	0
October	87	80	7	92	80	12	56	48	8	0	0	0
November	156	248	-92	148	254	-106	127	164	-37	24	32	-8
December	128	85	43	125	80	45	92	76	16	55	74	-19
Total	1,158	1267	-109	1,157	1,290	-133	780	832	-52	244	284	-40

operations except for tillage (98 to 156 h/ha), sowing/transplanting (16 to 29 h/ha), harvesting and transportation (15 to 34 h/ha) and plant protection operation (8 to 17 h/ha) among all farm categories (**Fig. 2**). **Table 3** shows that total requirement of human power was low (6,146 h/ha) for large farmers and maximum demand for small farmers (6,895 h/ha). This was because large farmers used highly efficient power source like tractor.

Availability and Demand of Animal Power

Monthly availability of animal power and demand for different farm categories are presented in **Table 4**. Maximum demand of animal power was in November for all the farm categories for most of the crops except large farmers. This was due to sowing of rabi and potato in this month. For large farmers this type of work was done by tractor power, so demand was low. Availability of animal power was surplus in most of the months except for January, July and November for marginal, small and medium size farmers. While large farmers faced a deficit of animal power in most of the months. A surplus of 13 h/ha was in June for large farmers. Maximum deficit of 106 h/ha was in November followed by 88 h/ha in January and 52 h/ha in July. This was due to sowing of rabi and potato in the month of November which demanded more animal power.

Peak demand of animal power was in November, January, and July among different farm categories. November encountered a variation of 32 to 254 h/ha, January faced a variation of 48 to 212 h/ha and July 32 to 160 h/ha (**Fig. 3**). Animal power was not used in the month of February for all farm categories because neither tillage nor post harvest operations (animal dependent) were done for the crops under investigation.

Operation wise Animal Power Utilization

Operation wise animal power availability and requirement for different farm categories showed (**Table 5**) that animal power was used for tillage, threshing and transportation. A deficit was observed for tillage for all categories of farmers and varied between 40 to 138 h/ha (**Fig. 4**). Total requirement of animal power was maximum for small farmers and minimum for large farmers and varied between 284 to 1,290 h/ha. This was because large farmers owned tractors.

Availability and Demand of Tractor Power

Monthly availability of tractor power and demand for different farm categories are presented in **Table 6**.

Table 6 shows that maximum demand of tractor power among all farm categories was in the month of March and May and ranged from 25 to 36 h/ha and 25 to 30 h/ha, respectively. This was due to transportation of potato and onion. Another maximum demand of tractor power was in the month of November for all farm categories and varied between 8.25 to 32.5 h/ha. This was because rabi wheat and potatoes would be planted during this month. This great variation in demand of tractor power from marginal to large farmers was because marginal and small farmers depend more on animal power, while medium and large farmers depend more on tractor power. Availability of tractor power for large farmers was surplus in most of the months except July and November for all crops. There was a deficit of tractor power in most of

Fig. 3 Peak animal power availability and demand in nalanda district

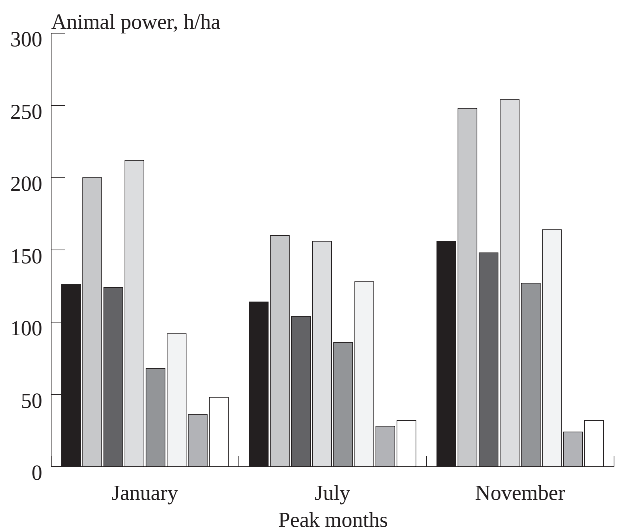
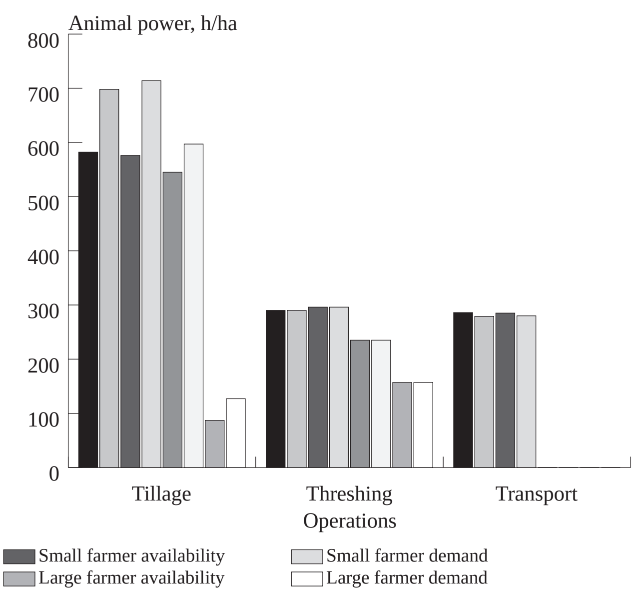


Fig 4. Operation-wise animal power availability and demand in nalanda district



the months among marginal, small and medium size farmers. However, a surplus of 3.5 was in the month of May for marginal farmers because they owned a tractor or power tiller. A maximum deficit of 5.25 h/ha was in November followed by 2.25 h/ha in January and 1.9 h/ha in July. This was because sowing of rabi wheat

Fig. 5 Peak tractor power availability and demand in nalanda district

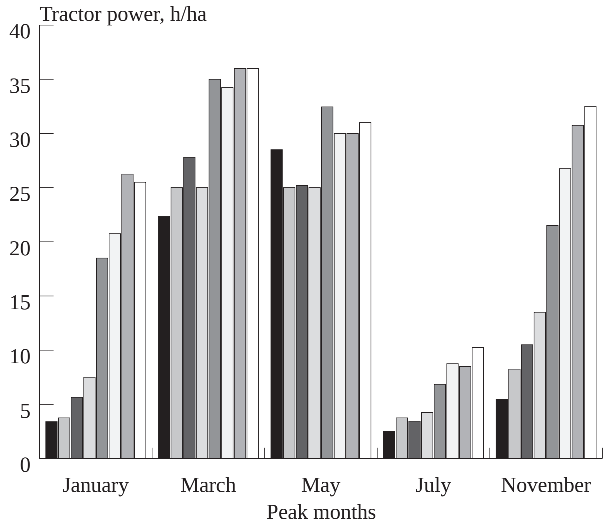


Fig. 6 Tractor power availability and demand in nalanda district

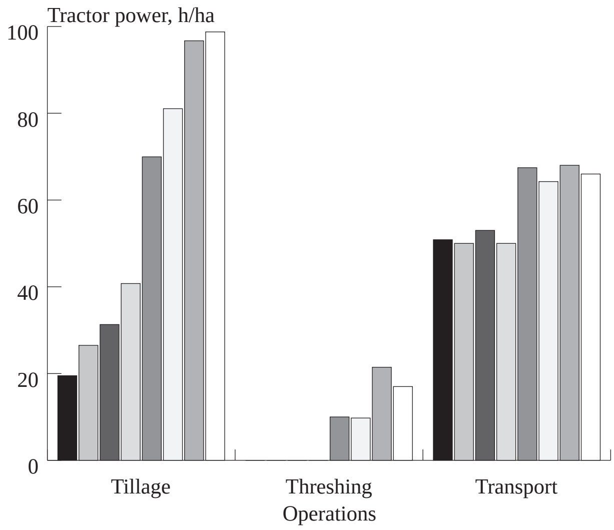


Table 5 Animal power availability and demand (h/ha) in nalanda district - under different farm operation

Operation	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def
Tillage	582	698	-116	576	714	-138	545	597	-52	87	127	-40
Threshing	290	290	0	296	296	0	235	235	0	157	157	0
Transport	286	279	7	285	280	5	0	0	0	0	0	0
Total	1158	1267	-109	1157	1290	-133	780	832	-52	244	284	-40

Table 6 Tractor power availability and demand (h/ha) - month wise in nalanda district

Month	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availa-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def	Avail-bility	Demand	Sur./Def	Availa-bility	Demand	Sur./Def
January	126	200	-74	124	212	-88	68	92	-24	36	48	-12
February	0	0	0	0	0	0	0	0	0	0	0	0
March	141	136	5	149	146	3	82	80	2	64	72	-8
April	84	72	12	86	72	14	77	76	1	0	0	0
May	72	68	4	81	76	5	0	0	0	0	0	0
June	78	72	6	72	64	8	58	46	12	37	24	13
July	114	160	-46	104	156	-52	86	128	-42	28	32	-4
August	96	82	14	98	78	20	72	74	-2	0	0	0
September	76	64	12	78	72	6	62	48	14	0	0	0
October	87	80	7	92	80	12	56	48	8	0	0	0
November	156	248	-92	148	254	-106	127	164	-37	24	32	-8
December	128	85	43	125	80	45	92	76	16	55	74	-19
Total	1158	1267	-109	1157	1290	-133	780	832	-52	244	284	-40

and potato in November, which demanded more tractor power (**Fig. 5**). Peak demand of tractor power was in November, March and May among different farm categories and varied between 8.25 to 32.5 h/ha; 25 to 36 h/ha; and 25 to 30 h/ha, respectively.

Table 6 shows that maximum deficit of tractor power among all farm categories was in November and it ranged between 1.75 to 5.25 h/ha. Total deficit of tractor power was 6.15 h/ha for marginal, 6.45 h/ha for small and 7.65 h/ha for medium size farmers. Whereas, a surplus of 3.4 h/ha for large farmer. Tractor power was not used in the month of April for marginal and small farmers. This was due to the fact that these farmers thresh wheat by stationary power source. Total tractor power requirement was maximum for large farmers (181.75 h/ha) and minimum for marginal (76.50 h/ha). This was because large farmers depend more on tractor power, while marginal and small farmers depend on animal power.

Operation wise Tractor Power Utilization

Operation wise tractor power availability and demand for different farm categories show (**Table 7**) that tractor power was used for tillage, threshing and transportation. A deficit was observed for tillage among all farm categories and it varied between 2.05 to 11.10 h/ha (**Fig. 6**). Marginal and small farmers did not use a tractor for wheat and paddy threshing. Total requirement of tractor power was maximum for large farmers (181.75 h/ha)

Table 7 Tractor power availability and demand (h/ha) in nalanda district - under different farm operation

Operation	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def
Tillage	19.5	26.5	-7	31.3	40.75	-9.45	69.95	81.05	-11.1	96.7	98.75	-2.05
Threshing	0	0	0	0	0	0	10	9.75	0.25	20.45	17	3.45
Transport	50.85	50	0.85	53	50	3	67.45	64.25	3.2	68	66	2
Total	70.35	76.5	-6.15	84.3	90.75	-6.45	147.4	155.05	-7.65	185.15	181.75	3.4

Table 8 Stationary power availability and demand (h/ha) - month wise in nalanda district

Month	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def
January	96	124	-28	102	125	-23	100	125	-25	110	126	-16
February	95	102	-7	94	100	-6	98	104	-6	110	106	4
March	98	120	-22	105	122	-17	102	123	-21	100	118	-18
April	103	135	-32	102	137	-35	102	132	-30	104	125	-21
May	45	32	13	46	36	10	45	34	11	38	30	8
June	52	44	8	54	46	8	53	44	9	50	45	5
July	48	40	8	52	40	12	55	42	13	51	42	9
August	0	0	0	0	0	0	0	0	0	0	0	0
September	36	27	9	35	24	11	32	22	10	32	24	8
October	78	64	14	82	65	17	75	63	12	70	64	6
November	62	35	27	60	36	24	66	38	28	52	40	12
December	85	82	3	87	86	1	85	85	0	85	83	2
Total	798	805	-7	819	817	2	813	812	1	802	803	-1

Table 9 Stationary power availability and demand (h/ha) in nalanda district - under different farm operation

Operation	Marginal Farmer			Small Farmer			Medium Size Farmer			Large Farmer		
	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def	Availability	Demand	Sur./Def
Tillage	727	733	-6	735	737	-2	741	747	-6	728	738	-10
Threshing	47	50	-3	58	55	3	52	50	2	49	45	4
Transport	24	22	2	26	25	1	28	25	3	25	20	5
Total	798	805	-7	819	817	2	813	812	1	802	803	-1

and minimum for marginal farmer (76.50 h/ha). This was because marginal and small farmers depend more on animal power.

Availability and Demand of Stationary Power Source

Monthly availability and demand of stationary power sources for different farm categories are presented in **Table 8**. Peak demand of stationary power requirement was in April for marginal, small and medium size farmers and ranged between 132 to 137 h/ha. This was due to coincidence of onion irrigation and wheat threshing. Large farmers generally used a tractor for wheat threshing. Peak demand for large farmers was in the month of January 126 h/ha. Availability of stationary power was surplus in most of the months except for January, February, March and April (**Fig. 7**). The deficit of power in these months was because potato, rabi wheat and onion cultivation was done during these months. These crops require higher irrigation water.

Farmers of all categories did not use stationary power in the month of August. **Table 8** shows that total deficit of stationary power for marginal and large farmers ranged between 1 to 7 h/ha. Whereas, a surplus for small and medium size farmers was observed and ranged between 1 to 2 h/ha.

Operation wise Availability, Demand and Utilization

Operation wise stationary power availability and requirement for different farm categories showed (**Table 9**) that stationary power was used for irrigation, threshing and hulling. A deficit was observed for irrigation among all categories of farmers and varied between 2 to 10 h/ha. A deficit of stationary power for threshing (3 h/ha) was observed for marginal farmers (**Fig. 8**).

Technological Gaps and Possible Solutions

Technological gaps were in various farm operations for growing paddy, potato, onion and pulse crops in Nalanda district. The farm operations could be performed in time if improved implements are used and crop yield would increase substantially. Paddy - wheat is the main crop rotation in this district and problem was faced for paddy harvesting and subsequently seed bed preparation and sowing of wheat. A reaper can be used for quick harvesting of paddy and improved tillage and sowing equipments could be used for seedbed preparation and sowing of wheat. A no till drill can also be used for direct sowing of wheat in some areas. Paddy thresher can be used for quick threshing of paddy crop. Water logging is the main problem of Tal area and pulse and wheat sowing is delayed due to late receding of water. The pulse and wheat sowing can be enhanced by using no-till drill without seed bed preparation.

Another problem of power deficit was in the month of July for paddy crop. The improved puddlers or rotavator can be used for quick puddling operation and transplanter (mat type seedling) can be used for paddy transplanting.

Improved wheat thresher or multicrop thresher can be used to overcome power deficit in the month of March and April. Similarly the improved implements for potato sowing, earthing and digging may be used for increasing yield of potato.

Onion is a very important case crop of this district that requires huge human labour in the month of

Fig. 7 Peak stationary engine/motor power availability and demand in nalanda district

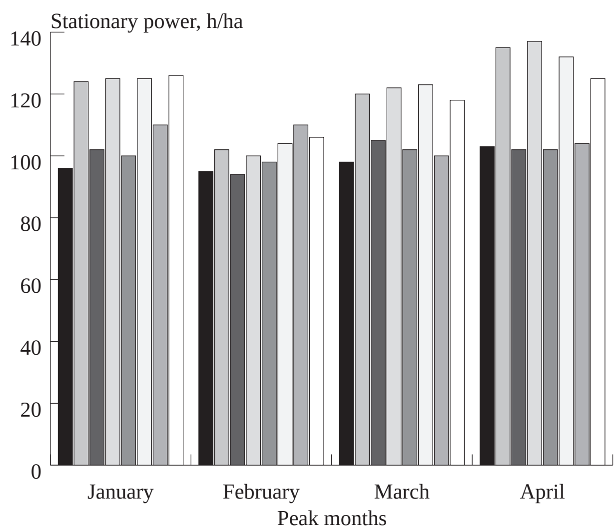
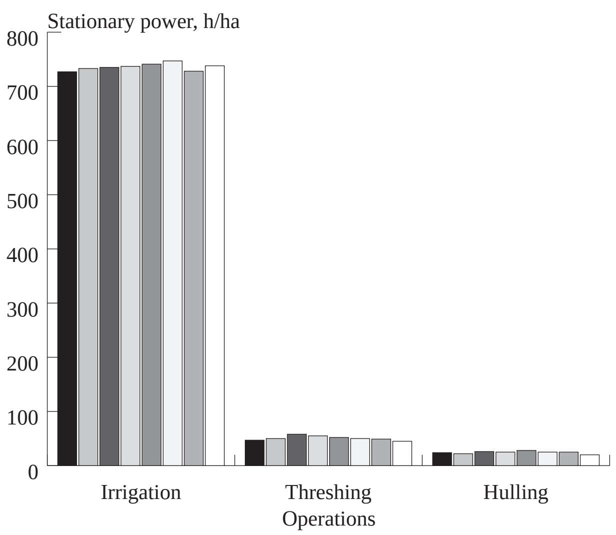


Fig. 8 Stationary engine/motor power availability and demand in nalanda district



January and February. There is need to develop planter, and digger for this crop. The hand tools or weeding equipments can be used for intercultural operation.

Conclusions

The following conclusions may be drawn from the present study :

1. The peak demand of human power per ha was about 2,058, 1,186, 536, and 1,836 hrs. in January, February, July, and November, respectively.
2. A deficit of human power was observed in the months of January (286 to 372 h/ha), February (194 to 261 h/ha), March (21 to 58 h/ha), July (59 to 95 h/ha) and November (182 to 252 h/ha) for all farm categories.
3. Maximum deficit of animal power was in November (106 h/ha) followed by 88 h/ha in January and 52 h/ha in July.
4. Total demand of animal power was more for small farmers (1,290 h/ha) and minimum for large farmers (284 h/ha).
5. Peak demand of tractor power was in November 8.25 to 32.5 h/ha, in March 25 to 36 h/ha and in May 25 to 30 h/ha.
6. Total deficit of tractor power was 6.15 h/ha for marginal, 6.45 h/ha for small and 7.65 h/ha for medium size farmers, whereas a surplus of 3.4 h/ha for large farmers was observed.
7. A deficit of tractor power for tillage among all farm categories was observed and it ranged from 2.05 to 11.1 h/ha.
8. A deficit of 2 to 10 h/ha for irrigation among all farm categories and a deficit of 3 h/ha for threshing for marginal farmers was observed.
9. Peak demand of stationary power was in April for marginal (135 h/ha), small (137 h/ha) and medium size (32 h/ha) and for large 126 h/ha in January.

REFERENCES

Gupta, P. K. and R. Soni. 1990 Energy use from different power source in Punjab agriculture. in Proceeding of International Agricultural Engineering conference and Exhibition, Bangkok, Thailand, 3-6 December, 1990.

Guruswamy, T. and et al. 1992. Utilization of farm power sources in the village Mansalapur of Karnataka - A Survey analysis. Indian Journal of Agricultural Engineering 2 (4): 249-255.

Guruswamy, T. and et al. 1993. Energy requirements of crop production under dry land agriculture in Karnataka: a case study. Agricultural Engineering Today. 17 (5-6): 90-97.

Srivastava, N. S. L. 1985. Status of Draught Animal Power in India and its Utilization in Rural Sector : A key note address. Silver Jubilee Convention, Indian Society of Agricultural Engineers, Central institute of Agricultural Engineering, Bhopal.

Shambhu V. B. and et al. 2005. A case study of farm power Utilization pattern in Nalanda District. presented in 39th Annual convention & Symposium of Indian society of agricultural Engineers (ISAE), ANGRAU, Hyderabad

■■

Evaluation of a Nylon Towrope for Buffering Pulling Forces of Animal-drawn Utility Wagons

by
Timothy M. Harrigan
Assistant Professor
Biosystems and Agricultural Engineering Dept.,
Michigan State University,
East Lansing, Michigan, 48824,
USA
harriga1@msu.edu

Richard J. Roosenberg
Executive Director
Tillers International,
10515 East OP Avenue,
Scotts, Michigan, 49008,
USA

Abstract

Pulling forces measured as tension in the towing device were evaluated for horse- and ox-drawn, steel-and pneumatic-tired farm utility wagons. A nylon towrope was compared to traditional horse-and ox-drawn harnessing components. Pulling forces were greater with steel tires than with pneumatic rubber tires, and pulling forces for the ox-drawn wagon were greater than for the horse-drawn wagon. There was no significant difference in pulling force between a nylon towrope and standard tugs on a horse harness, or a nylon towrope and a steel chain with an ox yoke.

Introduction

Over two billion people in 30 developing countries use draft animals for agricultural production and transportation (Ramaswamy, 1999). Productivity is often limited because implements are poorly designed and require more effort than needed to accomplish the desired task. The most common cause of painful harnessing of draft animals is poor equipment design or modification stemming from an inadequate understanding of the principles of traction and the functions of the parts of a hitching system (Hovell, 1998; Kumwenda, 1999). Well designed hitching systems can improve the working comfort and productivity of draft animals.

Pulling force is best evaluated within the context of the hitching system. Inns (1990, 1991 and 1996) demonstrated a reduction in tillage draft by increasing the hitch angle with an innovative high-lift harness and lightweight tillage implement for single animals. Hovell (1999) reported that a singletree, evener and long traces were key elements in improving draft efficiency because they balanced forces through the traces and provided traction evenly at a central point. An optimal hitch angle for most traditional neck yokes and collars passes through the animal's center of gravity to the hitch point at the yoke or collar (Bansal and Thierstein, 1987).

Compression springs are often used to protect animal-drawn tillage tools from damage caused by impact with stones or other obstructions. Extension springs can be placed between the heel chains and single-tree of a horse hitch, or in the towing chain of an ox yoke, and are said to absorb and store energy by offering an elastic resistance to the pulling force. Nylon towropes are a type of extension device perceived to be effective in mitigating high-end forces from towed implements. Anecdotal benefits of nylon towropes are: 1) a smoother start causes less wear-and-tear on the team and equipment, 2) a smoother start and steady pull provides a greater willingness to draw a heavy load, and 3) the team is able to move a load with less effort.

Little work has been reported in comparing draft buffering systems or in quantifying the practical benefits of draft buffers for work and transportation. Effective draft buffers that improve animal comfort and productivity can be an asset in meeting the energy needs of small farms. An understanding of draft forces and how they are transferred offers an opportunity to make improvements in hitching and harness systems.

Objectives

There is a need to evaluate draft buffers as a means to improve animal comfort and productivity in harness. The goal of this work was to compare standard tugs (horse hitch) or a towing chain (ox yoke) with a commercially available nylon towrope when pulling a farm utility wagon. Specific objectives were:

- Compare an average tension in the towing device for a utility wagon with pneumatic rubber or steel tires drawn with horses or oxen using either standard tugs or a nylon towrope.
- Evaluate the range and magni-

tude of pulling forces for the horse- and ox-drawn hitching systems.

Materials and Methods

Measurements of tension in the towing device for horse-and ox-drawn farm utility wagons were made in 2004. Two farm utility wagons, each with a mass of 2,773 kg, were evaluated at the Tillers International farm and training facility in Scotts, Michigan (42.221 N; -84.424 W). One wagon had 6.00-16 bias ply tires inflated to 207 kPa and the other had 14 cm wide steel tires with 69 cm front and 84 cm diameter rear wheels. The pneumatic-tired wagon had a steel roller bearing wheel assembly. The steel-tired wagon had greased, cast iron spindles (25.4 cm) tapering from 8.7 cm at the large end to 5.7 cm at the small end. Each wagon was drawn with either a team of horses (1,640 kg, 16° hitch angle) or a team of oxen (1,550 kg, 8° hitch angle). The horse hitch consisted of a standard collar harness with stitched, inelastic nylon traces (**Fig. 1**). A North American-style ox yoke with a dropped hitch point (Roosenberg, 1992) was used with a team of Milking Shorthorn steers (Bos taurus, 1,800 kg, **Fig. 2**).

Pulling forces with the standard horse traces were compared to the nylon towropes. The nylon towrope (19 mm diameter) consisted of woven nylon strands that formed a hollow shell. Within the shell was a 305 mm hard rubber core (22 mm diameter). Preliminary testing of the elastic response of the nylon towrope showed that it stretched 100 mm at a constant rate of 12.5 mm/1,000 N under an 8,000 N load. The rubber core stretched 25.4 mm under the 8,000 N load. Pulling forces were recorded while traveling north and south over three surfaces: 1) compacted soil covered with about 1-cm of loose dust, 2) compacted and firm dirt lane, and 3) recently mown hay ground.

Pulling force measurements were made with a hydraulic pull-meter with a pressure transducer on the discharge side of the cylinder. The pull meter was placed in the towing chain and the pulling forces were recorded at a frequency of 5 Hz with a monitor attached to the transducer. A sub-meter accuracy global positioning system receiver (GPS; Trimble 214) was used to record the position of the implement and match pulling forces with specific locations in the field. The geo-referenced pulling forces were stored in a hand-held, rugged, field computer (Trimble Ranger, AgGPS® 160 software). A computerized geographic information system (GIS) and farm management software, *Farm-Site* (CTN Data Service, 2004) was used to store, manage and display the pulling force measurements. Because the hitch angle varied from 8° with the ox-drawn wagon to 16° with the horse drawn wagon, comparisons of both the horizontal component (F_h) and the resultant pulling force (F_R) were analyzed.

Fig. 1 Horse hitch with collar harness and standard tugs drawing the utility wagon with pneumatic rubber tires

Fig. 2 Oxen with a North American-style neck yoke drawing the utility wagon with steel tires

Statistical Analysis

The three track surfaces at the *Tillers International* site were each 135 m long. Pulling forces were recorded when traveling in each direction. Adjacent 91.5 m transects were displayed and combined for each surface to form three experimental replicates (each replicate represented forces recorded over 183 m). Pulling forces recorded when the wagon was moving straight ahead were included in the pulling force measurements; pulling forces in turns were excluded. Pulling forces were analyzed as a 2 × 3 factorial with Power (horse or ox), Tire (steel or pneumatic rubber) and Tug (standard tug/chain or nylon towrope) as factors. An analysis of variance (ANOVA) was conducted using the General Linear Model in Minitab (Minitab Inc., 2003). Comparisons between the levels of factors to obtain confidence intervals for all pairwise differences were conducted using Tukey's multiple comparison tests with a family error rate of 0.05.

Results

Wheeled vehicles moving over a firm surface have considerable 'bounce' in the load–the vehicle surges ahead when the team steps into the yoke or collar because tires offer little motion resistance. Rubber-tired wagons have less bounce than steel-tired wagons because rubber tires offer less motion resistance than steel tires. The pulling forces for two farm utility wagons were evaluated and all combinations of *Power* (horse or ox), *Tire* (steel or pneumatic rubber) and *Tug* (standard tug/chain or nylon towrope).

The main effects of the horse- and ox hitch (*Power*) were highly significant ($p < 0.001$). The average F_h for the horse hitch was 1,601 N. The average F_h for the ox hitch was

1,941 N. The frequency of pulling forces for the steel-tired wagon with the horse hitch with standard tugs and the ox hitch with a steel chain are shown in **Fig. 3**. The pulling forces with the horse hitch were clustered near the mean pulling force of 2,038 N (skewness = 0.54, kurtosis = -0.79). The pulling forces with the ox hitch were skewed more to the high-end (skewness = 0.94). Although the average pulling forces between these treatments were not significantly different (*p = 0.141*), the ox hitch had a greater frequency of pulling forces than the horse hitch in all categories greater than 2,750 N.

The main effects of tire selection (Tire) were highly significant (*p < 0.001*). The average pulling force with the pneumatic-tired wagon (1,234 N) was less than the steel-tired wagon (2,308 N). The magnitude and frequency of pulling forces with the ox-drawn steel- and pneumatic-tired wagons with the nylon towrope are shown in **Fig. 4**. The distribution of pulling forces were skewed toward the high-end, but the pulling forces with the pneumatic-tired wagon were more tightly clustered around the most frequent range (750 to 999 N, kurtosis = -0.43) than forces for the steel-tired wagon (1,500 to 1,749 N, kurtosis = -1.07).

The use of steel tires with the cast iron spindles increased wagon draft 87 % compared to pneumatic tires with steel roller bearings. Pneumatic tires cushion the impact of stones and other obstructions, and deflect under load. As the load increases, tire deflection increases the tire/soil contact area. This provides a larger bearing surface, improves flotation, reduces tire sinkage, and reduces motion resistance and draft.

The main effects of the nylon towrope (*Tug*) were not statistically significant (*p = 0.87*). Average pulling forces for the ox (steel chain) or horse (standard tug) drawn wagon were 1,776 N (S.E. = 167) and 1,766 N (S.E. = 200) with the nylon towrope. There were no significant interactions between factors (*Power × Tire, p = 0.182; Power × Tug, p = 0.623; Tire × Tug, p = 0.146; Power × Tire × Tug, p = 0.468*).

Discussion

A harness should enable an animal to apply full force to a load and sustain a useful level of output over a period of hours without pain or tissue damage from poorly fitting equipment (Hovell, 1998). The pulling forces for the wagons were consistent with other reported work whereby pneumatic tire drafts ranged from 4 % to 10 % GVW and the use of steel tires increased draft by 50 to 100 % compared to rubber pneumatic tires (Harrigan et al., 2001). Although the cast iron spindle assembly likely created greater motion resistance than the steel roller bearings, logic dictates that the difference in pulling force due to the wheel assemblies was relatively minor. The horse hitch distributed the load through the two-horse evener, two single-trees, four tugs and two shock absorbing padded collars. Because the ox yoke transferred the pulling force through a single chain to the rigid yoke beam there was little ability to absorb the shock as the animals stepped into the load. Compared to the ox yoke, the horse hitch had a mitigating effect on high-end drafts.

An effective draft buffer must be designed with knowledge of the pulling forces that will be encountered. Owende and Ward (1999) reported significant speed-depth interactions that made speed an important parameter in tillage tool selection. Knowledge of interactions among important hitching and

Fig. 3 Frequency and magnitude of pulling forces in 250 kg increments for ox- and horse-drawn wagons with steel tires using standard tugs with horse hitch or a steel chain with an ox hitch

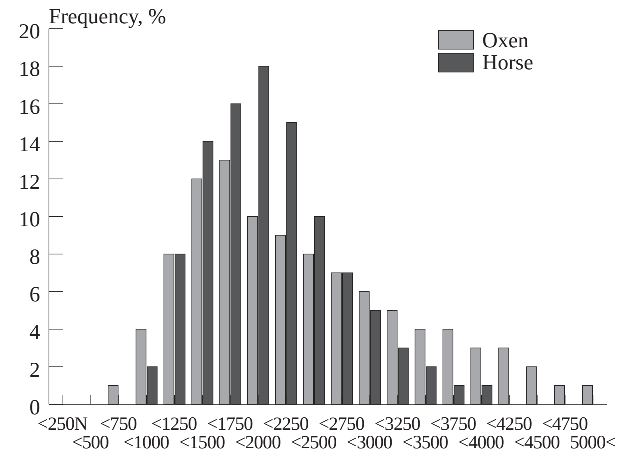
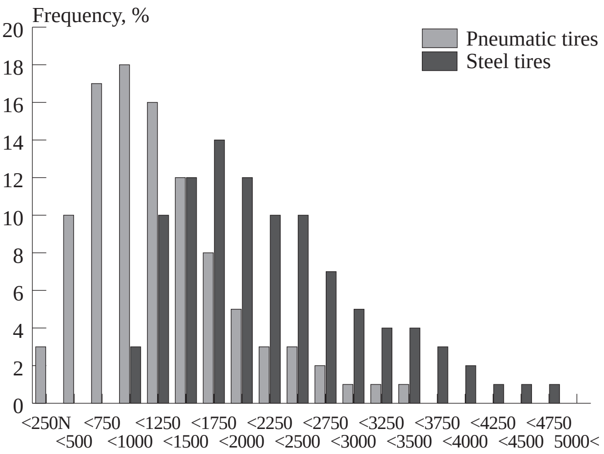


Fig. 4 Frequency and magnitude of pulling forces in 250 N increments for an ox-drawn wagon with either steel or pneumatic tires using the nylon towrope



harnessing factors can aide in buffer design and in matching draft buffers with tools and hitching systems. The α-level, or significance level, is the probability of incorrectly rejecting the null hypothesis of no difference between treatments when it is in fact true. Statistical tradition uses a default value of $\alpha = 0.05$, but in investigations of new processes the α-value is often set higher, perhaps at 0.10 or 0.20 to identify potentially important differences and interactions for further study. In the wagon study, the *Power* × *Tire* ($p = 0.182$) and *Tire* × *Tug* interactions ($p = 0.146$) satisfied such relaxed criteria.

The *Tire* × *Tug* interaction was in the lower pulling forces with the nylon towrope (1,178 N) than the steel chain (1,290 N) when using pneumatic rubber tires and greater pulling forces with the nylon towrope (2,354 N) than with the steel chain (2,263 N) when using steel tires. Because the pneumatic tires offered less motion resistance than steel tires, the force needed to advance the wagon likely more closely matched the elastic response of the nylon rope than the steel chain.

The *Power* × *Tire* interaction was in the greater increase in pulling force when drawing the steel-tired wagon with the oxen than with the horses (2,525 N versus 2,092 N) compared to the pneumatic-tired wagon (1,358 N versus 1,110 N). Presumably, the multiple components of the horse harness provide greater shock absorption than the ox yoke and steel chain.

The frequency and magnitude of pulling forces were similar for the ox-drawn, pneumatic-tired wagon with the steel chain (1,373 N) and the nylon towrope (1,343 N, **Fig. 5**). In contrast, when horses were used to draw the pneumatic tired wagon the Fh was 1,207 N with the standard traces and 1,013 N with the nylon towropes. When using the nylon towropes 36 % of the pulling forces were less than 1,000 N and 45 % were greater than 1,250 N (**Fig. 6**) When using standard tugs, only 21 % of the pulling forces were less than 1,000 N and 60 % were greater than 1,250 N. Perhaps the elastic response of the towrope more closely matched the resistance of the wagon with pneumatic tires. In such conditions a team would experience a more constant pull rather than the

Table 1 Pulling force, speed and power output for 2,773-kg ox- and horse-drawn wagons with pneumatic or steel tires using nylon towrope or standard tugs

	Pulling force, N*		Speed, kmh	kW
	Fr **	Fh		
Horses, pneumatic tires				
Standard trace	1,256a	1,207a	2.7	0.89
Nylon towrope	1,054a	1,013a	2.5	0.75
Horses, steel tires				
Standard trace	2,120b	2,038b	2.5	1.42
Nylon towrope	2,231b	2,145b	2.7	1.57
Oxen, pneumatic tires				
Steel chain	1,386a	1,373a	2.1	0.75
Nylon towrope	1,357a	1,343a	2.2	0.75
Oxen steel tires				
Steel chain	2,512b	2,487b	1.9	1.27
Nylon towrope	2,587b	2,562b	1.6	0.97

* Means within the same column followed by the same letter are not significantly different by Tukey's HSD procedure ($p < 0.05$)
** F_h refers to the horizontal component of the pulling force required to move the implement in the direction of travel. The tension in the towing chain $F_r = F_h / cosine\ \theta$ where θ is the angle of the line of pull from horizontal (newtons).

Fig. 5 Frequency and magnitude of pulling forces in 250 N increments for an ox-drawn wagon with pneumatic tires using either the nylon towrope or a steel chain

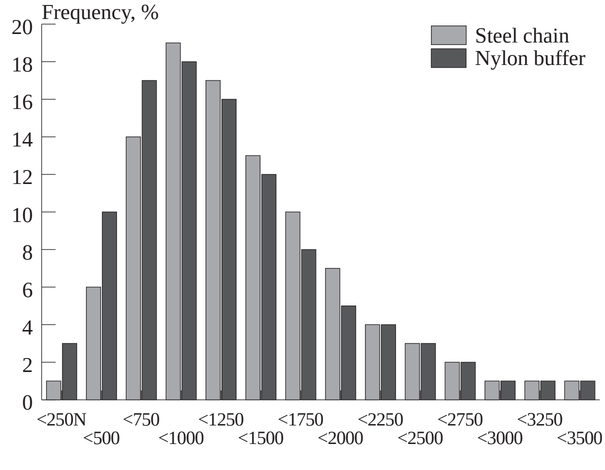
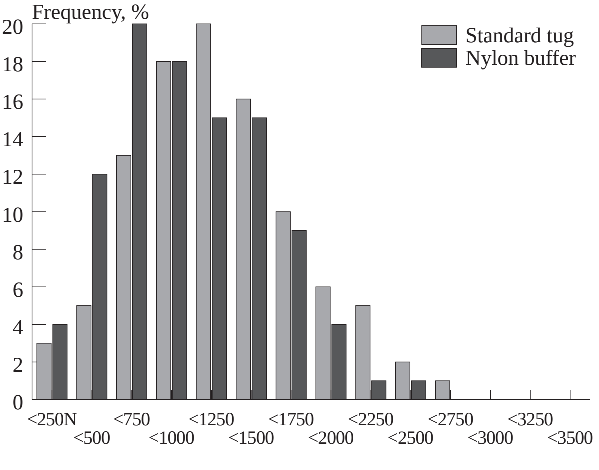


Fig. 6 Frequency and magnitude of pulling forces in 250 N increments for a horse-drawn wagon with pneumatic tires using either standard tugs or nylon towropes



shock loading likely to occur when a wagon pulses forward and releases tension in the tugs just as the team steps into the load and snaps the tugs taut.

Additional work is needed to identify significant interactions among harnessing and loading factors for the design of effective and efficient pulling systems that improve animal comfort and productivity.

Conclusions

- Tire and wheel selection had a significant impact on wagon pulling force. Compared to pneumatic rubber tires with steel roller bearing wheel assemblies, steel tires with tapered, greased, cast iron wheel assemblies increased pulling forces by 87 %.
- The horse hitch created significantly lower pulling forces than the ox hitch when drawing a farm utility wagon. Presumably, innate buffering effects of the multi-component horse harness reduced tension in the traces compared to the ox yoke and tow chain.
- There were no significant differences due to the nylon towrope in the average pulling force of horse- and ox-drawn, steel- and pneumatic-tired utility wagons compared to standard tugs on a horse harness or a steel chain on an ox yoke.
- There were no detectable differences in the frequency of pulling forces (grouped in 250 N increments) between a commercially available nylon towrope and a steel chain on an ox hitch or standard tugs on a horse harness.

REFERENCES

Bansal, R. K. and G. E. Thierstein. 1987. Engineering Considerations. In: An Introduction to Working Animals: Chapter 6. J L Falvey (Ed.), MPW Australia, Melbourne, Australia.

CTN Data Service, Inc. 2004. Farm Works Software. Hamilton, IN 46742-0250, USA.

Harrigan T. M., R. J. Roosenberg, D. Perkins and J. Sarge. 2001. Estimating Draft: Rubber and Steel-Tired Wagons. Rural Heritage 26(6):53-55.

Hovell G. J. R. 1998. Welfare considerations when attaching animals to vehicles. Applied Animal Behaviour Science 59: 11-17.

Inns, F. 1990. The mechanics of animal-draught cultivation implements. The Agricultural Engineer 45: 13-17.

Inns, F. 1991. The design and operation of animal/implement systems: guidelines for soil cultivation implements. In: Fielding, D. and Pearson, R.A. (Eds.) Donkeys, mules and horses in tropical agricultural development. University of Edinburgh, Centre for Tropical Veterinary Medicine. pp 258-265.

Inns, F. 1996. Matching tillage implements to draught animal potential. World Animal Review FAO 1996/1:40-49.

Kumwenda, W. F. 1999. Design and manufacture of a withers yoke for zebu oxen and cows. In: Starkey, P. and Kaumbutho, P. (Eds.), Meeting the challenges of animal traction. Animal Traction Network for Eastern and Southern Africa (ATNESA), Harare, Zimbabwe. Intermediate Technology Publications, London. pp 140-142.

Minitab, Inc. 2003. V. 13. Minitab, Inc., State College, PA 16801-3008, USA.

Owende P. M. O. and S. M. Ward. 1999. Reaction forces of lightweight mouldboard ploughs at slow speeds of tillage in Nitosol, Vertisol and Ferrasol soils under two moisture conditions. Soil and Tillage Research 49: 313-323.

Ramaswamy, N. S. 1998. Draught animal welfare. Applied Animal Behaviour Science 59: 73-84.

Roosenberg, R. J. 1992. Neck Yoke Design and Fit: Ideas from Dropped Hitch Point Traditions. Tillers' TechGuide. Tillers International, Scotts, MI., USA.

■■

The Influence of Some Parameters to Quality of Brown Rice After Husking on Small Productivity Rice Husker in the Rural Areas of Lamdong Province

by
Nguyen Hay
Associate Professor, Doctor
Vice Rector and Dean of Faculty of Engineering,
Nong Lam University
HoChiMinh City, VIETNAM
nguyenhay@hcm.fpt.vn

Pham Can
Master of Engineering
Lecturer of Department of Engineering,
BaoLoc High Vocational School
LamDong Province, VIETNAM
phamcancd@yahoo.com

Abstract

The main objectives of this work are:

1. To determine the influence of some parameters on the quality of husked brown rice from a small productive rice husker in rural areas that will increase the quality of milled rice and reduce specific energy consumption.
2. To determine the influence of some parameters on the quality of husked brown rice with the local available rice husker.
3. To identify the optimum husking conditions and minimum specific energy consumption determination.
4. Recommend to farmers and operators the best method to preserve paddy and control the husker in order to reduce the losses after husking.

Introduction

The cultivated paddy area in Vietnam is the sixth largest in the world, mainly in the Mekong River Delta, the Red River Delta, Central Coastal provinces and some places in Highland. The yield of paddy increased continuously in the past years due to innovative farming technique and improved high-yield paddy varieties.

In the rural areas, there are a large amounts of rice reserved for daily consumption and export. At the beginning, the primary aim of the rice husker-polisher was to supply white rice for daily consumption of local people. When the high-yield paddy breeds appeared, rice became a commercial merchant product. Rice husking and polishing systems in the rural areas play an important role to processed rice use for domestic consumption. Almost all rice milling factories with rural scale are used at remote regions and controlled by operators with lack of expertness. These factories are under farmer's private ownership. On the other hand, paddy breeds were changed from crop to crop and, as a result, there are many various kinds of rice. With all these above reasons, milling process losses are still high and the quality of milled rice is low.

Materials and Methods

Materials: The rubber roll husker model HW-60A, manufactured by Vinapro company, BienHoa, DongNai Province, Vietnam, has been widely used. The sample paddy was the IR168 variety that is a very popular cultivated variety at the research locality (Lam Dong province).

Research place: The research was conducted at Dateh and Cattien district, LamDong province. These two districts are typical for some places that have a large rice cultivated area per year in LamDong and also have many Ethnic Minorities. Because of low education level, exchanging technology to farmers is very necessary.

Experimental design: A completely randomized design was used. Treatments were distributed randomly by numbers and selected by lot. Sequence of experiments were also random.

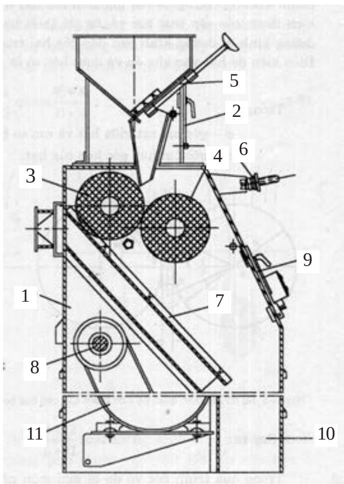
Experimental methodology: Research parameters were determined based on husking theory and experimental results were analysed based on the analysis of variance. Only a few parameters were researched that actually influence the quality of husked rice.

Experimental results were analysed by using experimental methodology of level one-if level one was not valid, level two was used. If both methods were not valid we designed the experiment again based on experimental range and added some elements if necessary.

Experimental data analysis method: applied Analysis of Variance (ANOVA) was used to evaluate the influence of research parameters to determine if the model was real or random. The Aknazarova (1982) method was applied to eliminate rough error. Excel software was applied to analyse the regression polynomial equation. Based on the Fisher standard, homogeneity of variance, fit of regression coefficients and accuracy of model were evaluated.

Optimization methodology: Optimum problems were found based on regression equation using the optimal method of multi-target equation. Excel software was applied to solve this problem.

Fig. 1a Structure of the rice husker



1. Husker frame; 2. Supply hopper; 3, 4. Rubber rolls; 5. Regulating valve; 6. Control handle (adjust clearance of rolls); 7. Slide discharge; 8. Pulley transmission; 9. Monitor door; 10. Duct discharge; 11. Motor

Fig. 1b Husker model HW-60A manufactured by Vinapro company-Vietnam

Results and Discusion

Research Parameters: The research parameters were moisture content of unhusked rough rice W (%), speed of main roller (high-speed roller) n (rpm), and clearance of rubber rolls δ (mm).

Output parameters : The output parameters were husking efficiency, Eh (%) and specific electrical energy consumption, Se (kWh/t).

Experimental results: The following regression equation was obtained after analysing the experimental data and eliminating not-fit regeression coefficients:

+ Husking efficiency (Eh)

$Eh = -386.0159 + 43.2930 \times W + 0.1503 \times n + 101.9214 \times \delta - 1.5178 \times W^2 - 0.00005 \times n^2 - 28.12 \times \delta^2 - 0.0283 \times n \times \delta$.

In the limit range of moisture content of paddy, husking efficiency was directly proportional to the moisture content; i.e. husking efficiency increased with increased moisture content. But when moisture content increased over the limit range, husking efficiency will reduced because of increased broken husked rice ratio.

Speed of the main roll and clearance of rolls were inversely proportional to husking efficiency. That is, with the speed of the main roll increased and with the roll clearance decreased, the husking efficiency was higher, of course in limit range.

Based on the first-degree polynomial coefficients in the husking efficiency equation, three factors influenced husking efficiency and were ranked as follow: clearance of rolls, speed of main roll and moisture content. Therefore, in the husking process the clearance of rolls were adjusted appropriate to paddy charateristics. **Fig. 2** showed influence of factors in pairs to husking efficiency.

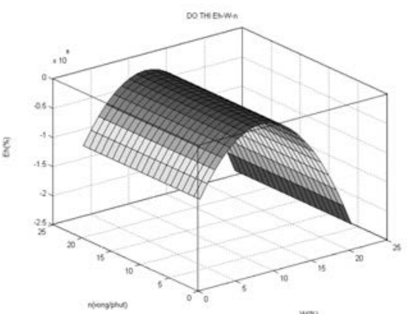
+ Specific electrical energy consumption, Se (kWh/t). $Se = 32.1140 - 2.3534 \times W - 0.0132 \times n - 4.4447 \times \delta + 0.0828 \times W^2 + 0.000005 \times n^2$

Optimum Problem Results:

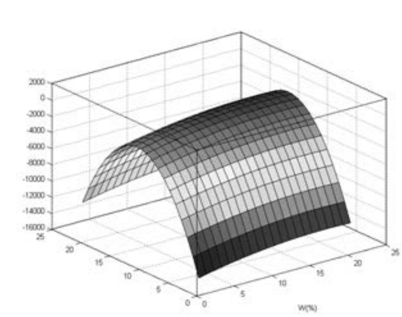
+ The maximum husking efficiency Eh_{max} = 70.51 %, correlated to optimal parameters: moisture content of paddy W = 14.25 %^{o}; speed of main roll n = 1200 rpm; and clearance of rolls δ = 1.5 mm.
+ The minimum specific electrical energy consumption, Se_{min} = 3.54 kWh/t, correlated to optimal parameters: moisture content of paddy W = 14.2 %; speed of main roll n = 1200 rpm; and clearance of rolls δ = 2.1 mm.

With the speed of the main roll higher, the specific electrical energy consumption was higher. They have a direct proportional correlation. With the moisture content and clearance of rolls lower, the specific

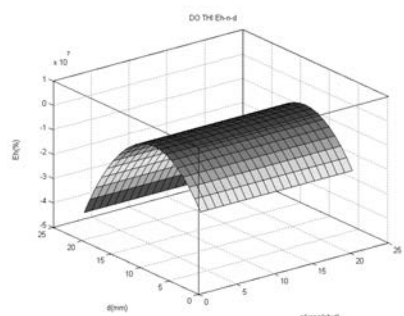
Fig. 2 Input factors in pairs to husking efficiency



1. Eh-W-n



2. Eh-W-δ



3. Eh-n-δ

electrical energy consumption was higher. They have an inverse proportional correlation. These result were fitted to the analysis above.

Based on the first-degree polynomial coefficients in the specific electrical energy consumption equation, the three factors that influence the specific electrical energy consumption are ranked as follows: clearance of rolls, speed of main roll, and moisture content. **Fig. 3** shows the influence of factors in pairs to specific electrical energy consumption.

+ Multi-target equation:

The maximum husking efficiency, Eh_{max}= 68.29 %, the minimum specific electrical energy consumption, Se_{min} = 3.66 kWh/t, correlated to optimal parameters: moisture content of paddy W = 14.23 %; speed of main roll n = 1117 rpm; clearance of rolls δ = 1.7 mm (**Table 1**).

Conclusion

Husking efficiency and specific electrical energy consumption are nonlinear equations dependent on moisture content of unhusked paddy, speed of main roll and clearance of rolls. These equations were shown in the quadratic equation form.

A moisture content of unhusked paddy (14 %) and a peripheral speed of (14 m/s) were fitted to the theoretical analysis and practical production. The peripheral speed was varried by controlling the speed of the rolls. Therefore, the speed of main roll was adjusted. Required clearance of the rolls depended on kind of local paddy. These techniques required the expertness of operator. This was a first stage to reduce rice processing losses at rural areas.

The target parameters above were determined by experiments on an existing husker, which was very popular in local area. Sample parameters were paddy breed that was cultivated widely in the local area. Based on research results the best moisture content of unhusked paddy was 14 %. Before husking it was necessary to adjust the main roll to the most suitable speed. At present, paddy is dried by sunshine. Also, low cost dryers could be used with rice husk used as the available local fuel. (e.g., SRR dryer manufactured by Nong Lam University, Ho Chi Minh city). In addition, in the operating process, the husker must be adjusted to achieve the best husking conditions.

REFERENCES

Truong Que Anh, Tran Thi Thanh Nguyet. 12/1999. Quality control of food material. Long An food company, Agricultural mechanical construction and installtion company.

Nguyen Canh. 2004. Experimental methodology. HoChiMinh National University Publisher

Tran Tri Dung. 2005. Excel-Solver for engineer. HaNoi Science and Technology Publisher

Dang Van Giap, 1997. Using Ms-Excel software to analyse scientific data. Education Publisher.

Nguyen Hay. 2004. Rice processing machinery. HoChiMinh National University Publisher

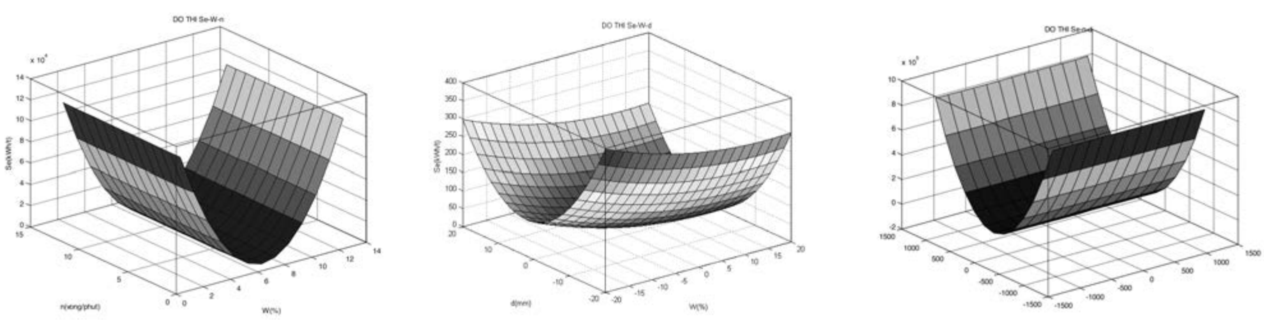
Phan Hieu Hien. 2001. Design experiment and analyse data methodology (Experimental statistics). Agricultural Publisher.

Nguyen Ngoc Kieng. 2000. Practice of optimization methodology on Excel and Statgraphics software. Nong Lam University, Ho Chi Minh city.

Harry Van Rutten. 1990. Rice processing technique - seminar organized at Nong Lam University, Ho Chi Minh city.

Toshihiko Satake. Modern rice-milling technology - Produced by University of Tokyo press.

Fig. 3 Graph of input factors in pairs to specific electrical energy consumption



1. Se-W-n 2. Se-W-δ 3. Se-n-δ

Table 1 Comparision between practical production and experimental results with the same kind of paddy

	Research parameters		Target parameters		
	moisture content, %	clearance of rolls, mm	speed of main roll, rpm	husking efficiency, %	specific electrical energy consumption, kWh/t
Practical production	12.5	1.5	1,230	62.25	3.9
Experimental result	14.2	1.7	1,117	68.29	3.6

Improved Cost Effective Implements for Small Rice Farmers

by

Jagvir Dixit
Assistant Professor (Agril. Engg.)
Division of Agricultural Engineering,
SKUAST-K, Shalimar,
Srinagar. -191121(J & K), INDIA
jagvirdixit@yahoo.com

J. N. Khan
Assistant Professor (Agril. Engg.)
Division of Agricultural Engineering
SKUAST-K, Shalimar,
Srinagar. -191121 (J&K), INDIA
junaid_k1974@rediffmail.com

Introduction

Kashmir valley of India has a suitable climate for cultivation of rice which is the most important field crop. The slope of the fields vary from mild to high and paddy crop is both in the valley and terraced land. The total production of paddy in Kashmir valley for the year 2001-02 was 75.7 M.T. on 40.40 m ha area, thus, giving an average yield of 1874 kg/ha. About 70 % area of the total cultivable area is under rice cultivation. Valley lands are mild sloppy areas and allow the water to flow from upper to lower side in such a way that there is continuity of flow from each field. However, terraces are located on higher slopes and rice is grown in these types of fields.

The average land holding size of the farming community is 0.5 ha. Tractors cannot be afforded when crops are grown in small terraced fields where easy access is not possible. The extent of farm mechanization is considered to be the indicator of the quality of farm life. Mechanization of farms helps in reduction of human drudgery besides ensuring the timeliness of operation and solving the problem of scarcity of labour during peak cropping season. It is an important means of increasing agricultural productivity through efficient utilization of biological and chemical inputs besides helping to achieve timeliness of operations and improving the quality of crop. Though modernizations and technology advancement is taking place at a rapid pace, yet there exist a large mechanization gaps in the region. Due to undulating topography and fragmentation of land in small pieces, the mechanization in Kashmir region is very limited. The changing socio-psychology and economy of the region are affecting the growth pattern of agricultural/horticultural crops and use of farm machinery in particular, which needs to be assessed. The tools, implements and machines developed in the rest of the country cannot be directly adopted in the region. Those are to be evaluated for feasibility and to be modified if required for the suitability.

Tillage Operation

Tillage operations, defined as mechanical manipulation of soil, are performed to achieve a desired seed-bed to provide optimum environment for seed germination and plant growth. Seed-bed preparation for sowing/planting of different crops is done through primary and secondary tillage operations. Loosening of soil is done to achieve a desired granular soil structure for a seed-bed and to allow rapid infiltration and good retention of moisture,

Fig. 1 Light weight power tiller in operation for seedbed preparation

Table 1 Field Performance of light-weight power tiller

Weight, kg	120
Width of tine, cm	50
No. of blades	16
Engine	Honda, petrol start, kerosene run
Operation	Rotary Tilling
Working width, mm	480
Depth of operation, mm	45-81
Field capacity, ha/h	0.05
Field efficiency, %	67
Soil pulverization, mm	8.2
Cost of operation, Rs./ha	952

to provide adequate air exchange capacity within the soil and to minimize resistance to root penetration and shoot growth.

Light Weight Power Tiller

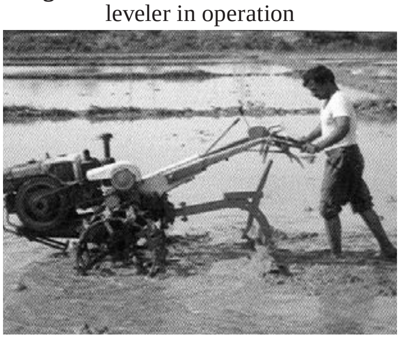
The available conventional power tillers in the Indian market are slightly heavy for hilly regions of the Valley, which makes them difficult to operate at higher altitude. Amar Light weight power tiller weighs only 120 kg, having 5.5 hp petrol start kerosene run engine as prime mover. The power tiller is light in weight, easy to operate and could be lifted from one terrace to other. The depth of operation can be varied by the adjustment provided in the rear side. It is suitable for tillage on sloppy and valley land, intercultural operation around the trees, weeding in orchards, vegetables and widely spaced crops, pumping and sowing.

Puddling Operation

The puddling operation is done for churning of soil in standing water for rice sowing/planting. It is done for preparation of paddy fields with standing water after initial ploughing. The main purpose of puddling is to reduce leaching of water, to kill weeds by decomposing and to facilitate the transplanting of paddy seedlings by making the soil softer. It is done in a standing water of 5 to 10 cm depth.

Fig. 2 Lugged wheel puddler in operation

Fig. 3 Power tiller mounted wetland leveler in operation



Lugged Wheel Puddler

The lugged wheel puddler is an animal drawn equipment to break the soil clods near saturation level into soil particles in order to prepare homogenized puddle tilth for mechanized paddy transplanting. The equipment consists of mainframe, hitch, operator seat, angle lugs roller wheel and leveler. It weighs 65 kg and the field capacity is 0.1 ha/h. Cost of the equipment is Rs. 3000/-.

Power Tiller Mounted Wetland Leveler

Farmers are using a wooden leveling plank and in certain places manual labourers are used to level wetland. This is a laborious, time consuming and costly operation. Moreover, perfect leveling cannot be achieved by these methods. The performance results of the wetland leveler are given below.

Sowing/ Transplanting Operation

The basic objective of sowing/planting is to put the seed/plant in rows at desired depth and maintain plant-to-plant spacing. The recommended row-to-row spacing, seed rate/plant population, plant-to-plant spacing and depth of seed/plant placement vary from crop and for different agro climatic conditions to achieve optimum yield. In manual seeding/planting, it is not possible to achieve uniformity in distribution of seed/plants. A farmer may sow/plant at desired seed rate/plant population but inter row distribution is likely to be uneven resulting in bunching and gaps in the field. The function of a well designed seeder or transplanter are to meter seed/plants and place them in the acceptable pattern of distribution in the field.

Manual Low Land Rice Seeder

During peak transplanting season, labour is scarce and this results in delayed transplanting with aged seedlings, which in turn affect productivity. To overcome this problem, farmers in many regions of the country have been practicing broadcasting for sowing rice. It has

Table 2 Performance of lugged wheel puddler

Overall dimension (l × w × h), mm	1095 × 1350 × 1130
Diameter of lugged wheel, mm	610
Weight, kg	62
Working width, mm	1130
Working depth, mm	85
Field capacity, ha/h	0.10
Field efficiency, %	71.4
Labour requirement, man-h/ha	10
Source of power	Pair of bullock
Cost of operation, Rs./ha	182

Table 3 Performance of power tiller mounted wetland leveler

Soil type	Black cotton, red
Speed of operation, km/h	1-1.2
Field capacity, ha/h	0.112-0.120
Field efficiency, %	67
Height of water level, mm	
Before leveling	20-50
After leveling	30-40

six rows with 200 mm row-to-row spacing. A lugged wheel is provided to drive an agitator in the drums to facilitate easy flow of pre- germinated seeds. The machine floats on two skids. Pre-germinated rice seeds are kept in two drums, which have peripheral openings at two ends for seed discharge. One person can pull the seeder easily. The seed flow can be cut off by closing the holes with the help of rings provided over the drums. Due to maintenance of rows at required spacing, the weeding and intercultural operation can be carried out easily using long handled tools. Cost of the equipment is Rs. 1500/- and field capacity is about 0.11 ha/h.

Fig. 4 Low land paddy seeder in operation

Fig. 5 Manual paddy transplanter in operation

Manual Rice Transplanter

Transplanting of rice is a labour intensive operation. For each cropping season, there is an optimum period during which rice should be transplanted for obtaining reasonably good yield. The demand for labour is at its peak during this period. Manual transplanting requires 200-250 man-h/ha, which is about 25 % of the total labour requirement for rice crop production. To overcome this problem, manual rice transplanters are available for small rice farmers. It is a six row manually operated equipment to transplant mat type rice seedling in puddled soil in rows. It consists of handle, picker assembly, seedling tray, tray indexing mechanism, main frame, base frame, seedling pushing lever, feeder link assembly, wooden skid and pivot arm assembly. The seedling tray consists of length and width of tray as 470 and 205 mm, respectively.

Initially mat type nursery has been raised. Partially perforated polythene sheet has been laid on the leveled land and the frame has been kept over the sheet and filled with soil. The sprouted seed (100 gm) has been uniformly sown manually in each frame (45.5 × 20 × 2 cm). The seed has been covered with a thin layer of soil and water has been sprinkled over that. The water has to be applied at least twice in a day by using a watering can. Seedling becomes ready for transplanting after 20-25 days. There is an optimum period during which rice should be transplanted for obtaining reasonably good yield. Manual transplanting requires 250-300 man-h/ha, which is about 25 % of the total labor requirement for rice crop production

Self-propelled Rice Transplanter

Rice transplanting is commonly carried out manually and it is labour intensive and time consuming. Delayed transplanting results in poor yield. Therefore, timeliness of transplanting is essential for higher yield of rice and the use of self- propelled mechanical transplanters have several advantages. It is a single wheeled driven with a 2.4 kW diesel engine. Transplanting system consists of fixed fork and knocks out lever type planting fingers. The machine covers 8 rows with 238 mm row spacing.

The study was conducted at CCS HAU Hisar shows that yield was 5.64 % more than manual transplanting. The machine maintained

Table 4 Performance of low land paddy seeder

Overall dimension (l × w × h), mm	117 × 132 × 145
Size of discharge opening, mm	6
Weight, kg	13.5
Working width, mm	1,000
Field capacity, ha/h	0.11 at speed of 1.44 km/h
Field efficiency, %	65
Labour requirement, man-h/ha	9
Source of power	one person
Cost of operation, Rs./ha	170

Table 5 Performance results of manual paddy transplanter

Row spacing, cm	20
Plant to plant spacing, cm	17
Planting depth, cm	3
Number of plant /hill	4
Missed hill, %	7
Number of plants/m^2	36-40
Floating hill, %	2
Plant damage due to working of machine, %	0.005
Field capacity, ha/hr	0.025
Labor requirement, man-h/ha	80
Field efficiency, %	66
Cost of operation, Rs./ha	495

recommended plant population.

Weeding and Intercultural Operation

Manually Operated Cono Weeder

Weeding is an important farm operation of good cultivation and increasing the yield. Farmers normally transplant paddy after puddling. Weeding is done manually. The introduction of paddy row seeder and transplanter has enabled paddy planting in rows. The newly developed weeders can be used efficient weeding in rows. The field trials of manually operated cono weeder at Various Universities in India show that the implement reduces drudgery due to less time taken (50-55 %) compared to hand weeding. The use of equipment also results in saving of cost of operation by 45 %. Farmers are of the opinion that cono weeder operation in standing position of operator allowed weeding without fatigue. Due to shortage of labour for timeliness of operation, farmers liked the equipment for enhancing productivity. The equipment proved socio-economically viable and acceptable to women labourers for faster and higher coverage.

Fig. 6 Self-propelled rice transplanter in operation

Fig. 7 Manually operated cono weeder in operation

Plant Protection Equipment

Chemicals are widely used for controlling diseases, insects and weeds in the rice crop. They need to be applied on plants and soil in the form of spray, dust or mist. Duster and sprayers are generally used for applying chemicals. Dusting, the simpler method of applying chemicals, is best suited to vegetables and is usually requires simple equipment. But it is less efficient than spraying, because of low retention of the dust. High volume spraying to some extent overcomes the failings of each of the above two methods while retaining the good points of both. A sprayer that delivers droplets large enough to wet the surface readily should be used for proper application. Different designs of spraying equipment have been developed for different types of application and field and crop condition. Knapsack sprayer, foot sprayer and duster are especially suitable for spray application in the rice crop.

Knapsack Sprayer

These are very common sprayers used by small and marginal farmers across the country. These are manually operated and mounted on the back of the operator. It is suitable for all the crops having standing height up to 1.0 m. it saves 72.8 % labour and 48 % cost over the manual spreading of chemicals. These are commercially available

Harvesting Operation

Rice crop is harvested after normal maturity with the objective to

Table 6 Performance results of self-propelled paddy transplanters

Parameters	Yanji	Yammar	LG	Kukji	Tong Yong	Asia
Planting depth, mm	0-60	15-45	15-45	15-40	15-40	15-40
Row spacing, mm	238	300	300	300	300	300
Hill spacing, mm	120 & 140	120-220	120-220	114-163	117-147	110-150
Seedlings per hill	2.25	2.2	2.2	2.3	2.3	2.3
Missing hills, %	7.3	4.6	6.8	7.4	8.2	7.2
Field capacity, sq. m/h	2,025	4,000	3,850	1,725	1,700	1,750
Labour saving, %	81	85	83	74	70	73
Cost saving, %	56	54	50	44	41	42
Cost of machine, lakhs	1.3	9	8	1.3	1	1.2

Table 7 Field performance results of manual cono weeder

Parameter	Observed values		
	KAU, Tavanur	UAS, Raichur	BAU, Ranchi
Soil type	Sandy loam	Loam	Clay
Field capacity, %	0.05	0.018	0.018-0.019
Weeding efficiency, %	78	50.4	66.45-68.33
Cost of operation, Rs/ha	425	328	322 -330
Field efficiency, %	60	60	64
Area covered, ha	448	4	14.13

take out grain and straw without loss. Harvesting of rice crop is traditionally done by manual methods of using a local sickle. The traditional sickle involves drudgery and is labour intensive. Rapid harvest facilitates extra days for land preparation and early planting of next crop. The use of improved tools or machine can help to harvest at proper stage of crop maturity and reduce drudgery and operation time.

Serrated Sickle

It has a serrated curved blade and a wooden handle. The handle of the improved sickle has a bend at the rear for better grip and to avoid hand injury during operation. Serrated blade sickles cut the crop by friction cutting like in saw blade. The crop is held in one hand and the sickle is pulled along arc for cutting. The average field capacity for different crops is 0.015 ha/hr., which is 40 % more than traditional sickle. It weighs 160 gm, which is much less as compared to traditional sickle and reduces muscular stress. It is made of spring steel and hence does not require frequent sharpening of blade.

Fig. 8 Knapsack sprayer

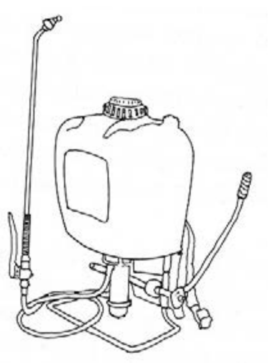


Fig. 9 Serrated sickle in operation

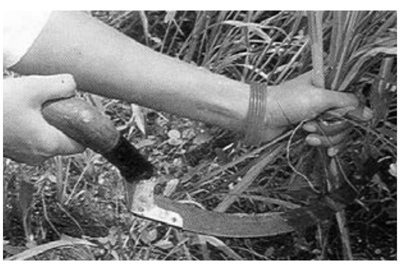


Fig. 10 Self- propelled vertical conveyor reaper in operation

Self- propelled Vertical Conveyor Reaper

Timely harvest of the crop is vital to achieve better quality and higher yield of the crop. The shortage of labour during harvesting season and vagaries of the weather is a problem faced by the farming community. The self?propelled vertical conveyor reaper is a timely solution to these farmers. The self-propelled reaper has been demonstrated for rice and wheat for different varieties and soil conditions at various parts of the country. It saves 50 % labour and cost of operation and 75 % operating time. The equipment gives negligible losses for paddy crop. The machine is safe to operate and can be moved rearward by using reverse gear. The height of cut of rice is acceptable to farmers. The machine works well at high soil moisture and for high crop moisture. The reaper covers 1.5 ha/day by employing two operators alternatively to avoid ill effect due to vibration of handle of machine. Mobility of the machine is convenient to farmers from one field to another field. The Vardan reaper of M/s Field Worthy Equipment gives high coverage and minimum fatigue due to provision of reverse system. The crops windrowed are easy to make bundles.

The crop can be cut close to the ground. For timeliness of operation during peak harvesting season, use of the self-propelled reaper is very useful for subsequent field operation for next crop.

Threshing Operation

Threshing is the process of detaching grains from the ear heads. Threshing of rice is based on the principle that when some impact or pounding is given on crop, the grains are separated from panicle. The rupture of the bond between the grains and ears is due to the factors, like (i) impact of beaters or spikes over grains and (ii) wearing or rubbing action. The strength of the bond between the grain and the panicle depends upon: (i) type of

Table 9 Field performance of knapsack sprayer

Dimensions (l × b × h), cm	55 × 25 × 60
Tank capacity, lit	8-10
Weight (without liquid), kg	3.5-4.5
Field capacity, ha/h	0.07
Nozzle Type	flood/ hollow cone
Operating pressure, kg/sq cm	1.5-1.7
Length of operator’s handle, cm	50-70
Cost, Rs.	1500-2000

Table 10 Field performance of serrated sickle

Overall dimension (l × w × h), mm	350 × 110 × 45
Length of cutting edge, mm	255
Width of cutting edge, mm	26
Radius of curvature (Inner & outer), mm	195 & 207
No. of teeth per cm	5
Weight, gm	160
Field capacity, ha/h	0.009 to 0.020
Labour requirement, man-h/ha	50-109
Cost of operation, Rs./ha	437-953

crop (ii) variety of crop (iii) ripening phase of grain and (iv) moisture content of grain. Rice is generally threshed by beating bundles on a wooden log or iron drum, which is a slow and labour consuming process generally do threshing of rice. With the increase of mechanization, different types of manual or power operated paddy threshers have been developed.

Paddy Thresher (Hold On)

Paddy threshing is mainly done manually by beating bundles on a wooden log or iron drum. Due to uncertain weather conditions, farmers do not find sufficient time to dry the harvested crop. In this region, paddy straw has commercial use and it is utilized for packing fruits apart from being used as cattle feed. Handle operated, pedal operated and motorized wire loop type paddy threshers are available commercially. The division of Agricultural Engineering (SKUAST-K), Wadura, Sopore has developed a paddy thrasher on which three men are able to perform the threshing operation. The thresher consists of rotating drum mounted on a shaft which has crate wire sprocket drive operated by one man similar in action to that of paddling a bicycle.

Two men can hold the paddy bundle on separate segments of the rotating drums and once the grain bearing portion is brought in contact with rotating spikes, the grain is separated from the awn almost effortlessly, eliminating the drudgery which otherwise the labour has to undergo in the conventional method of threshing, viz. beating the bundles against a log or drum. The threshing can be done at a comfortable speed of 150-200 rpm, and depending upon the requirement, can be performed at a speed of up to 500 rpm. For small holdings, it is acceptable due to less drudgery and more output than hand beating.

Fig. 11 Self-propelled vertical conveyor reaper in operation

Fig. 12 Pedal operated paddy thresher in operation

Conclusion

Improved tools and machines play a very important role in the development of agriculture. The points that the extension engineer has to keep in mind, are that of helping the farmers to make the selection of tools according to requirements and perceived constraints. All the farmers will not require the same tools or the machines. The capacity of farmers to buy the tools is also important. Sometimes the institutional support in the introduction of technology and mechanization is to be encouraged. The banks play a very vital role in providing the finances but they are mostly interested in the capacity of farmer to pay back the loan. The companies interest is to sale the product and many times they want their products to be subsidized by developmental agencies. Hence, as professional, they have to provide support to the farmers to make the right choice and selections for the tools and machines. As most of the hill farmers are small and marginal, they will mostly depend on the manually operated tools and equipment. Therefore the tools, which are scientifically designed, tested and useful, must be introduced. Many times the work capacity of farmers does not match the operational requirements, resulting in rejection of technology after it is introduced. Hence, application of socioeconomic and human considerations in agricultural tools and machines play a very vital role and it should be given due consideration in introduction of technology in order to achieve the development of hill agriculture.

REFERENCE

Annual Report and Proceedings of XXV workshop of AICRP on FIM held at PAU, Ludhiana w.e.f. February 10-13, 2004.

Annual Report of ICAR Adhoc Project "*Prototype feasibility testing of farm implements and machinery in selected regions of Jammu and Kashmir*".

Sahay, J. Elements of Agricultural Engineering. Standard Publishers Distributors, Nai Sarak, Delhi-110006.

Table 11 Effect of threshing methods on the threshing capacity, efficiency and energy requirement at different moisture content

Moisture content of the paddy crop, %	Thresher capacity*, kg/hr		Threshing efficiency, %		Energy requirement, MJ/q	
	Conventional method	Paddy thresher	Conventional method	Paddy thresher	Conventional method	Paddy thresher
22.1	85.3	250.25	97.9	96.3	6.89	2.35
20.2	95.0	259.10	98.5	97.5	6.19	2.27
19.8	100.0	266.35	98.9	98.2	5.88	2.21
Mean	93.33	258.57	98.43	97.33	6.32	2.28

*3-man power involve in both the case, conventional method and paddy thresher

Development and Modeling of Mobile Disintegrator

by

S. M. Bhende
Senior Scientist
All India Coordinated Research Projects
on Farm Implements and Machinery,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola (MS) 444-104, INDIA
bhendesm@yahoo.co.in

N. P. Awate
B E (Mechanical) Student
Shri Sant Gajanan Maharaj College of Engineering,
Shegaon (MS)
INDIA

D. S. Karale
Tech. Assist
All India Coordinated Research Projects
on Farm Implements and Machinery,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola (MS) 444-104, INDIA
dhiraj_karale@hotmail.com

S. P. Trikal
Prof. Dept. of Mechanical Engineering
Shri Sant Gajanan Maharaj College of Engineering,
Shegaon (MS)
INDIA

V. P. Khambalkar
Assist. Prof.
UCES & EE, CAET,
Dr. Panjabrao Deshmukh Krishi Vidyapeeth,
Akola (MS) 444-104
INDIA

Abstract

During the cultivation season a huge amount of crop residue and biomass is produced from grasses. The cotton crop alone produces 2.5 to 6.0 tones/ha of crop waste. Likewise sorghum, sugarcane pulses and similar crops produce millions of tones of crop waste per year. In the present situation there is no adequate machine available to disintegrate such material for making compost. To overcome from such difficulties a machine was designed and developed on Computer Aided Design (CAD) to understand the performance of the product before actually making the prototype and to identify modifications needed. After development of the final CAD drawing of the machine, it was checked by the simulation module, CATIA. During the simulation program the machine clearance between beaters and fixed blades permitted the determination of the size of crushed material and output rate. The present machine design is for an output rate of 1.5 tones/h.

Introduction

A real breakthrough in productivity has come and is expected to elevate the extensive application of mechanization on Indian farms. Cotton, sorghum and pulses are the major crops of Vidarbha region of Maharashtra state. The cotton crop alone produces about 2.5 to 6.0 ton/ha of crop waste. Sorghum and pulses also yield about 0.5 to 1.0 ton/ha. This huge available biomass in the field has nutrient value. In addition weeds grow voluntarily in varied conditions in the fields with cultivated crops as well as in uncultivated and cultivated areas through out the year. Many weeds are highly selective in the absorption of certain ions and are rich in major and trace elements.

The N content of weeds is 2.09 % P content 0.37 % and K content 1.42 % (Nagmani et al., 1995). It is a matter of great concern that this huge amount of mass left in the field is burned, used as a fuel or thrown away as waste because of the non-availability of a desirable machine. Keeping the above fact in mind, this study was initiated to design and model a mobile disintegrator for the better management of crop residue. Computer Assisted Design (CAD) was used for standardization of design drafting to know the performance of the product before actually making the prototype and to identify modification needed.

Literature Review

Particle size variability after chopping mildly increases with the variability in initial particle length and strongly decreases with leaf fraction (Pitt, 1987). A smaller range in allowable orientation angle of initially long particles relative to the direction of feeding is predicted to enhance the control over the size distributions of chopped forages significantly.

Jambhekar (1992) claimed that crop residues and other wastes, which are complex and cellulotic, require more time for decomposition. However, the decomposition of organic material will be complete within 45 days, if the organic wastes are inoculated with the earthborn culture.

Theoretical Consideration

The theoretical concept of each technical term and scientific approach is very essential for easy grasp of the study. Hence, this chapter concentrates its attention on definition of various scientific terms and different considerations of a manually operated disintegrator.

Machine and Its Working Principle

It is very difficult to reduce size of the crop residues such as cotton, sorghum and pigeon pea. Animal or human can develop high power for short time but they can not work continuously like electrical/mechanical power. Continuous high energy is required to reducing the size of the crop residues. With a flywheel of appropriate weight, it is possible to developed high energy for size reduction. A flywheel used in a machine serves as a reservoir, which stores energy during the period when supply of energy is more than the requirement and releases it during the period when the requirement of energy is more than supply.

A mobile disintegrator is a machine that reduces the size of the crop residues. The mobile disintegrator works on the principal that the crop is first broken by swinging beaters rotating with high rpm and then impacts the material on the fixed flail knife that fractures and disintegrates the residue into small pieces.

Design Methodology and Selection of Components

Design of Shaft

Data given

N = 1400 (PTO) and P = 22 HP = 16.4 KW

Now, *Torque* $= 60p/2\pi N = (60 \times 16.4 \times 10^3) / (2\pi \times 1400) = 111.33$ N.M.

Weight of each beater (L-shape) = 0.64 kg

V = l × b × h = (0.150 + 0.057) + (0.04) + 0.010 = 8.28×10^{-5} m^3

Weight = volume × density = $8.28 \times 10^{-5} \times 7850 = 0.64$ kg

Since there are six beaters on one impeller and there are six impellers so there are a total of 36 beaters, and the total weight of beater is 0.64 × 36 = 23.04 kg

Weight of impeller $V = \pi/4 \times d^2 \times t = \pi/4 \times 0.28^2 \times 0.006 = 3.69 \times 10^{-4}$ m^3

Weight = V × g = $3.69 \times 10^{-4} \times 7850$ = 2.90 kg Hence, weight of one impeller is equal to 2 × 2.90 = 5.8 kg. Therefore, total weight of six impeller = 6 × 5.8= 34.8 kg. Total uniformly distributed load on shaft = lot of 36 beater + wt of six impeller = 23.04 + 34.80 = 57.84 kg = 57.84 × 9.81 = 567.41 N

Hence, U.D.L. one 1000 mm shaft = 567.41/1010 = 0.561 *kg/mm*, Now, Maximum bending moment M = (*W* × *L)*/8 = (567.41 × 1010)/8 = 71635.51 N mm and Equivalent Torque, Te

$$\sqrt{(kt \times T)^2 + (k_m \times M)^2} = \sqrt{(1.5 \times 111.33)^2 + (2 \times 71635.51)^2}$$

∴ Te = 220259.38 *N. mm*

Equivalent Bending Moment Me =

$$\frac{1}{2}\left[k_m \times M + \sqrt{(k_m \times M)^2 + (K_t \times T)^2}\right]$$

$$= \frac{1}{2}\left[2 \times 71635.5 + \sqrt{(2 \times 1635.5)^2 + (1.5 \times 111.53 \times 10^3)^2}\right] = 727060.76 \text{ N/mm}$$

1. Dia. of shaft considering Te = $220259.38 = \pi/16 \times F_5 \times d^3$

   ∴ $d = 29.89$ *mm*, assume $f_5 = 42$

2. Dia. of shaft considering Me: $M_e = \pi/32 \times F_b \times d^3 = 220259.38 = \pi/32 \times 84 \times d^3$

   ∴ $d = 44.50$ *mm*, standard size of shaft = 50 mm. Checking for stresses = $220259.38 = \pi/16 \times F_b \times 50^3$ ∴ $Fs = 8.97$ *N/mm*^{2}

Calculated shear stress is less than design stress, so design is safe, now checking for bending $M_e = \pi/32 \times F_s \times d^3 = 727060.76 = \pi/32 \times F_s \times 50^3$, $F_b = 59.24$ N/mm^2. So design is safe. Now, Tangential force (F_t) = Torque/radius = 220259.38/280 $f_1 = 786.64$ N

Design of Key

Te = 220259.38 N. mm ∴ $Te = t \times w \times f_{sk} \times d/2$ (widening hearing)

Assume, W = d/2 for Rectangular Key T = d/6, 220259.38 = t × 50/4 × 42 × 50/2, ∴ $t = 16.78$ mm. Therefore, Te = 1 × t/2 × F_{CK} × d/2 = 220259.38 = 1 × 50/12 × 84 × 50/2

l = 25.17 ≅ 26 mm

By imperial correlation L=1.57d. ∴ $l = 1.57 \times 50$ ∴ $l = 78.55$ *mm*. Checking for Stresses $Te = l \times$ w × f_s × d/2 = 220259.38 = 78.5 × 123.5 × f_s × 50/2 ∴ $f_s = 8.97$*N/mm*^{2} So Key is safe.

Checking for Crushing $Te = l \times t/2 \times f_{CK} \times d/2$ = 220259.38 = 78.5 × 8.33/2 × f_{CK} × 50/2 ∴ f_{CK} = 26.94*N/mm*^{2} So design is safe.

Design of Pin

Assuming pb=10 N/mm^2, $W = P_b \times d \times l$ 786.64 = 10 × *d* × 50

∴ $d = 16.35 \cong 16$ *mm*

Considering factor of safety = 5

d = 3.27 × 5 ≅ *16 mm* 4, therefore, maximum bending moment on pin, M = (W × L)/4 = (786.44 × 50)/4

M= 9833 N/mm ∴ $Z = \pi/32 \times d^3 \Rightarrow \pi/32 \times 16^3$ ∴ $Z = 402.12$ *Nmm*^{3}

F_b = M/Z ∴ 9833/402.13 ∴ F_b= 24.45 *N/mm*^{3}

Calculated F_b is less than maximum stress, so the design is safe. The pin is checked for induced shear stress. The pin is in double shear, therefore, the load on the pin is

$W = 2 \times \pi/4 \times d^2 \times F_{sb}$ ∴ F_{sb}= 1.956 *N/mm*^{3}

so design of pin is safe.

Impeller

The impeller is chosen as the thickness of the plate that is 6 mm and two plates are mounted on the boss. The diameter of the boss is 70 mm and length is 60 mm.

Beater

The beater is the heart of disintegrator so as the agro-technical requirement to fulfill very nicely the thickness, total length and bending radius are 10 mm, 197 mm and 10 mm, respectively.

Selection Methodology

Pulley

1400 rpm is required on the main shaft, but there is 540 rpm on the P.T.O. shaft, thus, the speed must be increased by the ratio

N_2/N_1 is 1400/540 = 2.59

Dimension of the standard pulleys are

Pulley No. 1 = 280 mm - 2 groove

Pulley No. 2 = 100 mm

Pulley No. 3 = 100 mm

For feed roll reducing the rpm of shaft to 190 rpm

$\therefore\ N_3/N_1 = D_3/D_1$

$= 190/540 = D_3/280$

Belts

For transmission of the power, D_3 100 mm selecting the V belt

1. V Belt (1) - 1613.10
2. V Belt (2) - 2605 mm

Plumber Block and Bearings

The plumber block is selected according to the dimension of main shaft, lay shaft and feeders. The inner diameter of the bearing required is 50 mm, for all four shafts. So, the bearing $50BCO_2$ and inner and outer diameter is as 50 mm and 90 mm, respectively. The width of the bearing is 30 mm and thickness of race 4 mm with a maximum permissible speed of 8000 rpm.

Gears

The gears are selected according to the required module and slandered size available.

Computer aided Design (CAD)

Computer aided design (CAD) can be defined as the use of a computer

Table 1 Modeling and commands used for various parts 1

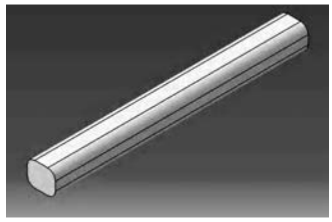
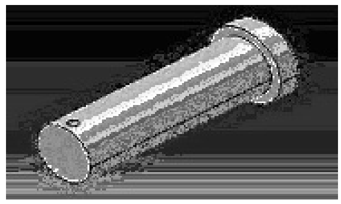
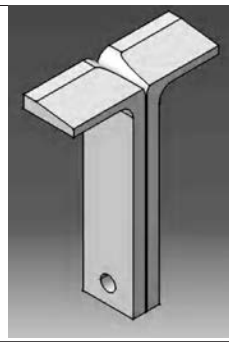
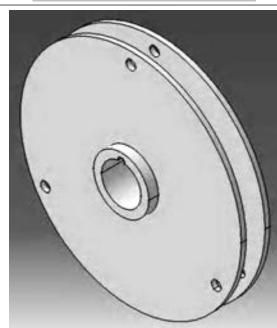
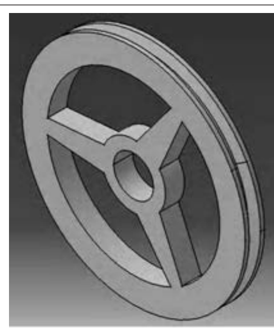
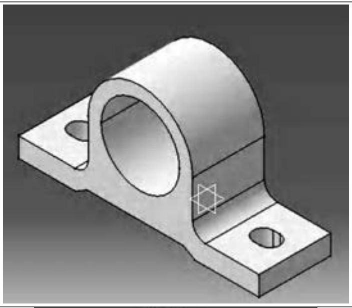
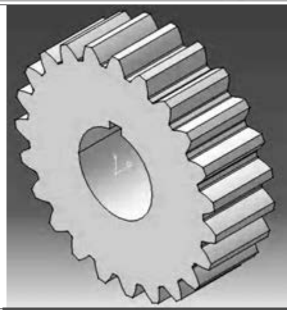
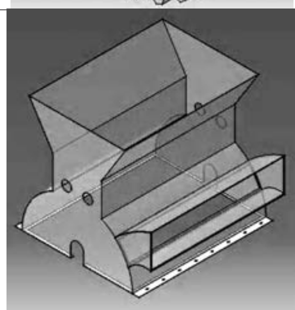
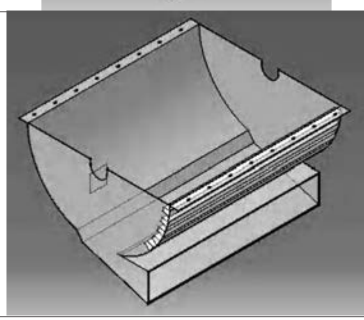
Part Name	Command Used	3-D Model
Shaft	Pad, Pocket, Chamfer	
Key	Pad, Chamfer	
Pin	Pad, hole, Chamfer	
Beater	Pad, fillet, hole	
Impeller	Pad, Pocket, hole pattern	
Pulley	Pad, Pocket, Chamfer, mirror	

Table 1 Modeling and commands used for various parts 2

Part Name	Command Used	3-D Model
Plummer Block	Pad, Pocket, Chamfer, mirror	
Gear	Pad, Pocket, circular pattern	
Top Hopper	Sketch, extrude, pocket shell chamfer, rectangular pattern	
Bottom Hopper	Sketch, extrude, pocket shell chamfer, rectangular pattern	

system to assist in creation, modification and analysis or optimization of design to perform the specialized design functions required by the particular user firm. We have used CATIAV5R15 (Shayam Tickoo et al., 2005) for modeling and simulation of mobile disintegrator.

Simulation

A powerful feature of CAD is simulation to help the designer with kinematics, robotics assembly and FMS design to identify the performance of the product before actually making the prototype. The modeling and commands used are cited in **Table 1**.

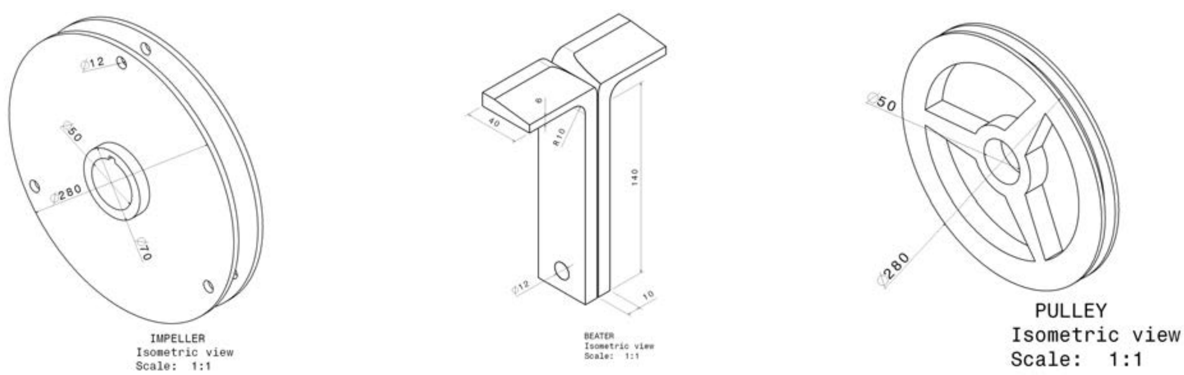
Result and Discussion

The Mobile Disintegrator is designed for a required output rate of 1.5 tones/hour. For the consideration of output rate the densities of pigeon pea and cotton wood waste are determined by experimentation carried out at Strength of Material Laboratory. The strength of pigeon pea and cottonwood are found to be 1003 in transverse and 77.11 in double shear by using the Universal Testing Machine. (**Tables 2 and 3**)

The beaters are chosen for the strength of more than strength of Pigeon pea and cottonwood.

The shaft is designed by considering torsion and bending and design is found to be safe. The shock and fa-

Fig. 1 Selection of different components of a disintegrator



a) Impeller selection b) Selection of beater c) Pulley selection tigue factor (Km) for bending is assumed as equal to 2 and shock and fatigue for torsion (Kt) is assumed as equal to 1.5. Although, due to this factor, the design is bulky but this is necessary as there is variation in torsional and bending stresses in shaft because of varieties of feeding material and their properties.

The pin is designed by considering bearing pressure and centrifugal force. Each component is modeled in CATIA V5R15 and assembled in the same. The dynamics of each mechanism is visualized and checked with the help of simulation module of CATIA. Simulation helps to decide the clearance between beaters and fixed blades so as we can decide the size crushed material and output rate.

Conclusion

1. The modeling along with the simulation provides the better visualization of the entire machining process and interpretation of the results of variation in its parameters (viz; feed rate, power, rpm) on the output. It may further help in detecting the area/part where the major concentration should be given during the design so as to retain the efficiency of machine.
2. It is concluded that the peripheral speed of the beaters is suitable for disintegration of the cotton pigeon pea and sorghum crop residue and the transmission system is suitable for effective transmission of power through PTO shaft of tractor.
3. The fixed clearance between beater and flail knife did not affect the variation in the total output and the particles size of disintegrated materials with respect to change of the screen. The characteristics of the crop residues affected the final output and particle size obtained.

REFERENCES

Jamkar, H. A. 1992. Use of earthworm as a potential source to decompose to organic waste. Proceedings of National Seminar on Organic Farming: 52

Nagmani, K. V; M. Rajgopal, Sitasamayya and M. V. Shataram. 1995. Chemical composition of some weeds species growing at APAU. Trans. of ASAE: 21(2) 113-115.

Pitt, R. E. 1987. Theory of particle size distribution for chopped forage. Trans. of ASAE: 30(7). 2362

Shayam Tickoo, Dipak Maini and Vicky Raina. 2005. CATIA V5R15 for Engineers and designers. Dreamtech Press, New Delhi.

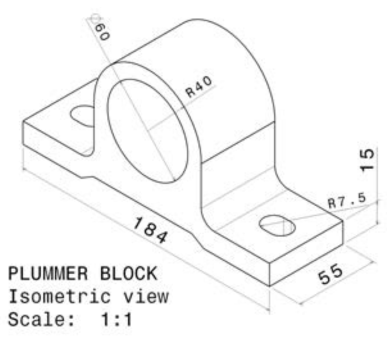
Table 2 Transverse test on pigeon pie and cotton stalk

Diameter, mm	Peak Load , kN	Transverse Strength, N/mm^2
16	4.04	881.625
12	4.48	1003

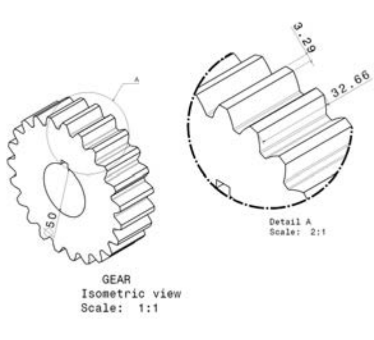
Table 3 Double shear test on pigeon pie and cotton stalk

Diameter, mm	Peak Load, kN	Shear Strength, N/mm^2
6.5	5.12	77.11
8	5.72	56.89

Fig. 1 Selection of different components of a disintegrator.

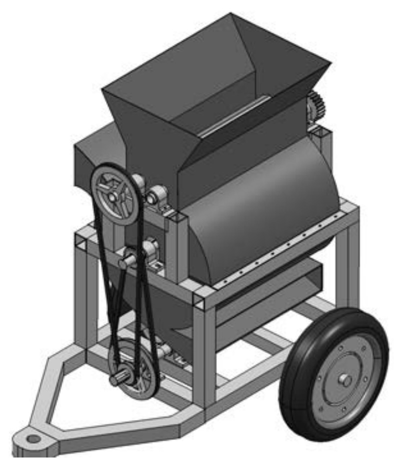


d) Plumber block selection



e) Gear selection

Fig. 2 Tractor operated mobile disintegrator assembly



Development and Performance Evaluation of Tractor Operated Plant Uprooter for Castor Crop

by

H. B. Solanki
Senior Research Assistant,
College of Agril. Engineering & Technology,
Junagadh Agricultural University, Junagadh,
Gujarat - 362 001
INDIA

Rajvir Yadav
Professor
College of Agril. Engineering & Technology,
Junagadh Agricultural University, Junagadh,
Gujarat - 362 001
INDIA
hbsolanki1970@yahoo.com

Abstract

A study was conducted for performance evaluation of local practices used for plant uprooting for castor crop. The result reveled that plant uprooting by local practices was expensive, time consuming and had lower plant uprooting efficiency with higher draft and power requirement. The designed plant puller consisted of a frame (1200 × 400 mm size) similar to a cultivator, two curved tynes (450 × 65 × 25 mm size) and three different blades, i.e. straight shape, V-shape, curved shape (600 × 150 × 25 mm). This was tested against the locally used straight shape blade (800 × 150 × 25 mm) at the Dry Farming Research Station, Gujarat Agricultural University, Sardar Krushinagar, Banaskantha for comparative performance evaluation at three depths of operation, 25, 35 and 45 cm. Soil type of the test plot was loamy sand and, at the time of planting, uprooting and moisture content was 8.01, 8.06 and 8.10 % (d.b.) at three respective working depths. Bulk density was 1.64, 1.64 and 1.65 g/cc at three working depths.

The curved shape blade was more promising with an uprooting efficiency of 87.6 % and field efficiency of 0.143 ha/h as compared to others. Cost of operation, energy requirement and draft were minimum at 1,954.70 Rs/ha, 842.20 MJ/ha and 825 kgf for curved blade as compared to straight shape, V-shape and locally used straight shape blade. The overall performance of the stalk uprooting blades was computed in term of performance index at different depths of operation and was highest (7.80 × 10-4) for the curved shape blade at 35 cm depth. Overall performance of the curved shape stalk uprooting blade for castor crop was found superior as compared to straight, V-shape and local straight blades.

Introduction

Castor is one of the important non-edible oil seed crops. India is the largest producer of castor in the world with annual production of 850,000 tons from 800,000 hectares. Gujarat ranks first in area under cultivation, production and productivity in India with 78.44 % of the total production of India from 44.43 % area under cultivation (Anon., 2006).

Clearing of the castor stalks from the field after last picking of the castor capsules has three basic processes; namely uprooting the stalk, gathering and stacking of the uprooted plants and then removing them from the field. Generally, The clearing operation of the castor stalk is done manually by using spade or hand plant puller popularly known as "Chipiyo". It is not possible to pull out the stems of deep-rooted crops like cotton, pigeon pea, castor crops with hands but, can be very well pulled out by the developed hand plant puller (Parikh, 1983). Adhaoo et al. (1992) stated that a mechanical lever locally called "Kamsha" or "Chimta" requires 10-24 man-hours for pulling cotton plants of one hectare, which is arduous and time consuming operation. Sheikh et al. (2000) states that some stalks were broken at the grasp point of the manual plant puller (Chipiyo) leaving the lower portion of the stalk and root system in the soil due to dry and brittle stalks at the time of removing. The plants and stalk breakage was also due to the great pressure applied to overcome the adhesive forces between soil particles and root system and angular pulling action with the puller.

Pothecarey and Ofield (1968) developed the Bobby machine at Agricultural Product International Ltd. (API) that pulled the plants of cotton from the soil. This machine was a 2 row pulled type implement driven from the tractor pto. It had a capacity of 0.2 ha/hr with 98 % plant removal efficiency. Sharma et al., (1993) developed a machine using M.S. flats and one cycle wheel. The overall dimensions of machine were 1640 × 455 × 955 mm. The stalk puller was capable of pulling the plants of 12-17 mm stem diameter and root diameter ranging from 17-24 mm with average root length of 216.9 mm at 10-13 % moisture of the field.

Pannu et al. (1997) developed a two-row tractor operated cotton stalk up rooter at Department of Farm Power and Machinery, PAU Ludhiana. This two-bottom machine consisted of two spring steel blades attached to the mild steel sub-soiler tynes. The tynes were attached to the frame of trapezoidal shape to divert the crop from coming in front of the frame to avoid clogging. It was operated with 35 hp tractors at average depth of 11-14 cm. The draft requirement was 450 kgf and 570 kgf, respectively. It was quite useful for cotton plant uprooting with effective field capacity ranging from 0.16 to 0.32 ha/hr. Anonymous (2001) developed a tractor operated plant/stalk puller for pulling the stalks of cotton, castor, and pigeon pea crops. This puller gave pulling efficiency of 97.96 % and an average draft of 325 kgf at a forward speed of 3.2 kmph for cotton stalk uprooting. For castor uprooting, there was a pulling efficiency of 94.69 % with an average draft of 475 kgf at a forward speed 3.6 kmph. For pigeon pea stalk uprooting in black soil condition there was a pulling efficiency of 92.53 % with forward speed of 2.6 to 3.0 kmph.

FAO (1977) stated that the shape of the sub-soiler tynes affect the draft requirement of the implement. Curved and bent shaped tynes require 25 % less pull as compared to straight tynes. Nichols and Reaves (1958) illustrated the effect of the shape of sub-soiler tynes upon draft. They operated three different shaped, i.e. moderately curved, most curved and straight stand tool at 36 cm depth in highly compacted clay soil. The straight stand tool had a draft of 12.4 KN. The moderately curved sub-soiler had 16 % less draft than straight tool and 1 % more than the most curved tool. In another comparison, tilting the straight standard tool backward 150 from the vertical reduced the draft 12 % and with a curved standard reduced the draft by 28 %.

Manual plant uprooting of the deep-rooted crops like cotton, pigeon pea and castor is a very slow, tedious and expensive operation. Mechanical plant uprooting is generally made by a heavy hoe. A MB plough and straight blade cultivator require higher draft, more power and has low plant uprooting efficiency. The tractor-operated stalk uprooting machines with hydraulic energy conversion are beyond the reach of the average farmers due to higher cost and more power requirement. Therefore, a project was undertaken to design and develop a suitable uprooting machine for castor crop.

Materials and Methods

Castor Plants Uprooting Practices

Castor plant uprooting is done manually by using spade and hand plant puller (Chipiyo). Another method of removing the castor plants from the field is to slash at ground level by sickle or scythe or cut below the ground level with a heavy hoe or harrow. Both these methods are slow and leave castor roots to grow and hence need uprooting. Tractor drawn straight blade attached to cultivator tynes is largely used for castor plant uprooting operation.

All the uprooting equipment was tested at Dry land Research Station, G.A.U, S. K. Nagar. Performance parameters, viz. theoretical and effective field capacity, plant uprooting efficiency, fuel consumption, energy requirement and operational cost, were recorded and calculated by conducting field trials. Observations are presented in **Table 1**.

Spade

Spade is a well-known agricultural tool. It is made of iron sheet with wooden handle. The stalks of the castor crop are dug out by spade in a specific posture. This practice requires more labours and is a very slow, time consuming and tedious process.

Hand Plant Puller

The hand plant puller, popularly known as 'Chipiyo' is designed and developed by Agricultural Tool Research Center, Bardoli (Gujarat).

Table 1 Comparative studies of different methods of castor stalk uprooting

Parameters	Spade	Hand plant puller	Tractor operated MB plough	Local straight blade
Variety	GCH-4	GCH-4	GCH-4	GCH-4
Spacing, cm	90 × 60	90 × 60	90 × 60	90 × 60
Depth of operation, cm	--	--	35.0	35.0
Average moisture content, %	8.0	8.0	8.0	8.0
Area covered (EFC), ha/h	0.009	0.01	0.099	0.12
Time required (hrs) for uprooting, 1 ha	110.25	100.45	10.05	8.33
Uprooting efficiency, %	100.0	100.0	65.0	70.8
Fuel consumption, l/h	--	--	3.7	2.3
Labour charge, Rs/h	10.0	10.0	300.0	250.0
Cost of operation, Rs/ha	1,102.5	1,004.5	3,015.0	2,082.5

This hand plant puller is quite successful in pulling out the stalks of deep rooted crops like cotton, pigeon pea and also thick, hard stemmed crops like maize, sorghum etc. The plant stem is gripped between the grip of the plant puller and, by applying force to the handle, the stalk is pulled out (**Table 1**).

The farmers of this region largely use this hand tool for uprooting plants of the castor crop. But, the stem of the castor crop is not hard but delicate and if it is gripped between the grip of the plant puller, the stalk cuts at the point of grip. This method is very slow, time consuming and tedious.

Tractor Operated Mould Board Plough

This is primary tillage equipment largely used for deep ploughing. Some farmers also use the tractor mounted MB plough for uprooting castor plants in this region. This traditional practice is quite successful especially in black soil. But, in sandy soil, plants escape on either side of the plough nose, which retards uprooting efficiency and causes unbalance of the plough during operation with higher draft requirement (**Table 1**).

Straight Blade Attached with Cultivator Tynes

This practice is largely used for castor plant uprooting everywhere in Gujarat. In this practice, a straight blade 80 cm long attached with tynes of 180 cm long cultivator frame is used for removing castor stalks. A straight blade cultivator requires higher draft, more power and low plant uprooting efficiency **Table 1**.

The taproot of the castor plant penetrates deep due to the characteristic of sandy soil and availability of water at higher depth in this region. So, the depth of operation for castor stalk uprooting was 25, 35 and 45 cm from the ground surface

Design Parameters

Morphological characteristics of castor plants were studied to identify that the size of the uprooting blades and depth of operation were correct. Depth of the taproot, spreading area of the root zone and thickness of the taproot were measured for randomly selected twenty-five castor plants from the test plot. Depth of taproot ranged from 38.12 -58.35 cm and the diameter of the spreading area of root zone was 60 to 70 cm. The thickness of taproot at 40-50 cm depth from ground surface was minimum, ranging from 3.12-1.48 mm. Considering this, the length of the designed blade was 60 cm. Three different depths, i.e. 25, 35 and 45 cm, were selected on the basis of root geometry for comparative evaluation.

Functional Requirement

Provision was made for adjustment of rake angle of the blade to achieve required depths. Plant uprooter should give maximum field efficiency and uprooting efficiency with lower draft and power requirement. Considering these, the tractor operated plant uprooter for castor crop was designed.

Constructional Details

The constructional features of the tractor operated castor plant uprooter mainly consisted of frame, up-

Fig. 1 Detailed dimensions of designed frame of castor stalks uprooter

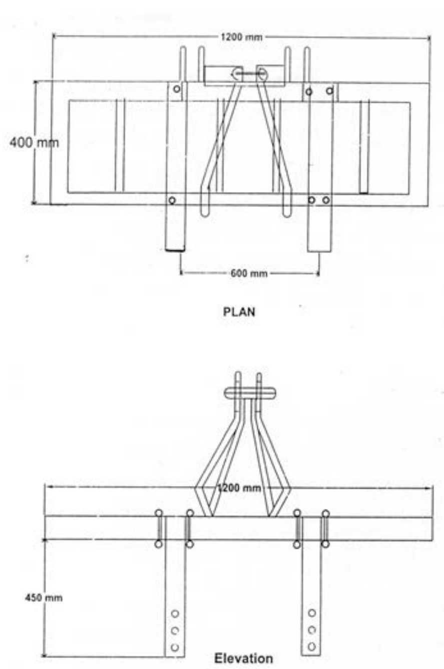
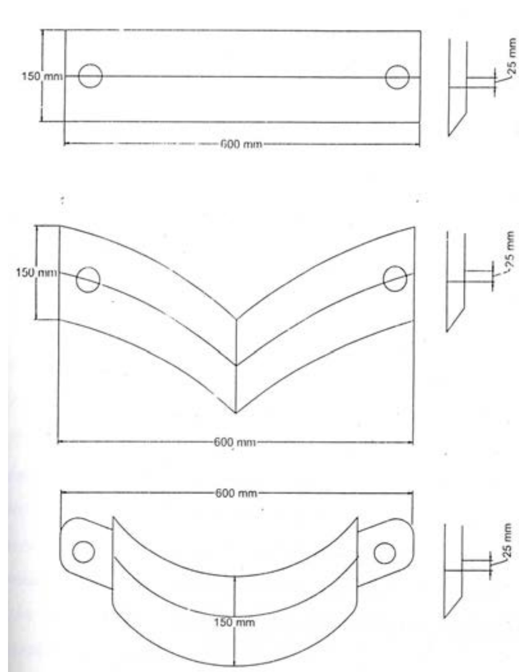


Fig. 2 Detailed dimensions of straight, V-shape and curved shape castor stalk uprooting blades



rooting blades and tynes. The versatile implement, cultivator frame of 1200 × 400 mm size was fabricated from 60 × 60 × 6 mm M.S.Angle with 12 mm drilled holes at interval of 80 mm on both sides to suit the setting of the tynes for various row spacing of the crop. The detailed dimensions of the frame of castor stalk uprooter are shown in **Fig. 1**.

Three different shape (i.e. straight shapes), V-shape and curved shape of uprooting blades were fabricated of 600 × 150 × 25 mm size from 120 × 12 mm high carbon steel flat. Straight and curved shape blades were made reversible type and the V-shape blade was fabricated having a flare angle of 1,200 (**Fig. 2**).

Two curved tynes through which the uprooting blade was attached to the frame of the plant uprooter were fabricated from 60 × 25 mm M.S. flat by proper heat treatment. The lower end of the tynes was drilled with 12 mm holes to facilitate the setting of rake angle of the blade for required depth of operation. Detailed dimensions of the designed curved tyne is shown in **Fig. 3**.

Field-testing of designed straight, V-shape and curved shape blades of 60 cm length along with a locally used straight blade of 80 cm length was conducted on February 2004 at Dry Farming Research Station, Gujarat Agricultural University, Dantiwada campus, Sardar Krushinagar, Banaskantha district of Gujarat state (India). The blades were operated at 25, 35 and 45 cm depth with a 35 hp tractor for GCH-4 variety of castor sown at 90 × 60 cm spacing. Size of the test plot was one hectare for each test, which was divided into subplots of 0.02 ha. During testing, the observations were depth, draft, fuel consumption, speed, effective field capacity, number of cloggings, time loss in turning and adjustments. A complete set up of the designed castor stalk uprooter is shown in **Fig. 4**.

The cost of operation was determined considering the prevailing rate of Rs.80 per day for labour and Rs.2,000 per eight hour day for the tractor with operator. Two labours were required for collection and removal of uprooted plants from field.

Results and Discussion

Performance evaluation of stalk uprooting blades:

Performance evaluation has been discussed in detail in terms of effective field capacity, uprooting efficiency, power requirement, cost of operation and performance index (**Table 2**).

Effective Field Capacity

Effective field capacity was higher for curved shape blade than straight shape, V-shape and local straight blade at all three depths of operation. The highest effective field ca-

Table 2 Comparative performances of stalk uprooting blades at different depths of operation

Type of blade	Depth, cm	Effective field capacity, ha/h	Uprooting efficiency, %	Metric, hp	Cost of operation, Rs/ha	Performance Index × 10^{-4}
Straight shape blade	25	0.130	73.6	8.8	2,029	5.35
	35	0.115	83.6	7.7	2,294	5.44
	45	0.105	86.0	8.0	2,512	4.49
V-shape blade	25	0.134	72.0	8.9	1,968	5.50
	35	0.120	80.8	7.8	2,198	5.65
	45	0.108	83.6	8.4	2,442	4.40
Curved shape blade	25	0.143	78.0	9.26	1,845	6.52
	35	**0.138**	**85.2**	**7.88**	**1,912**	**7.80**
	45	0.123	87.6	9.37	2,145	5.36
Local straight blade	25	0.125	66.0	7.7	2,143	4.99
	35	0.120	70.0	7.9	2,232	4.76
	45	0.095	74.0	7.2	2,819	3.46

Fig. 3 Detailed dimensions of designed curved tyne

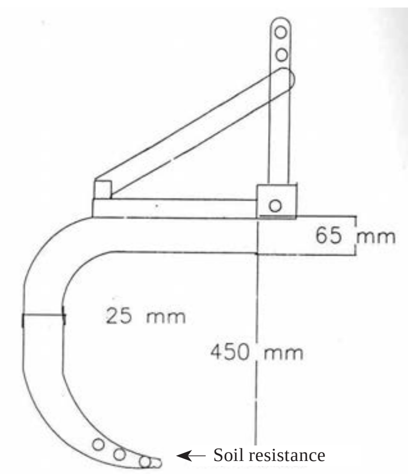


Fig. 4 Complete set of designed castor stalk uprooter

pacity, 0.143 ha/h, was observed for curved shape blade at 25 cm depth as compared to 35 and 45 cm depths (**Table 2**).

Uprooting Efficiency

Sample testing was conducted to determine uprooting efficiency. Sample area was taken as 4.5 × 6.00 m2 and replicated five times for each test. The numbers of complete uprooted and partially uprooted (called non-uprooted here) were collected and noted separately for each blade at all the three depths of operation. Uprooting efficiency was calculated as the ratio of the number of complete uprooted plants to the total number of plants of sample area (**Table 3**).

It was concluded from Table 3 that curved shape blade gives higher uprooting efficiency at 25, 35 and 45 cm depths than straight, V-shape and local straight blades. The highest uprooting efficiency observed was 87.60 %, when curved shape blade was operated at 45 cm depth.

Draft Requirement

Lower draft requirement was observed in case of curved shape blade than straight, V-shape and local straight blade at all the three depths (**Fig. 4**). The lowest draft, 825 kgf, was observed when the curved shape blade was operated at 25 cm depth of operation (**Table 3**).

Performance Index

The overall performance of the uprooting blades can be expressed in terms of performance index, which can be defined as below

$$\text{Performance index} = \frac{\text{Output parameters}}{\text{Input parameters}}$$

Where,

Output parameters = Effective field capacity, ha/h × Uprooting efficiency, %

Input parameters = Horse power, hp × Cost of operation, Rs/ha

Table 2 shows that the calculated performance index was decreased as depth of operation increased for straight, V-shape, curved shape and local straight blade and it is concluded that the overall performance of the curved shape blade was superior to straight, V-shape and local straight blade at all the three depths of operation. The highest performance index was found as 7.80 × 10-4 for curved shape blade at 35 cm depth of operation.

Economic Comparison of Stalk Uprooting Blades

The economic comparison of the different shape of the uprooting blades has been discussed in detail in terms of man-hour requirement, energy consumption and cost of operation.

Man-hour Requirement

Man-hours required for uprooting of plants and collecting and removing uprooted plants for a specific area was noted for straight, V-shape, curved shape and locally used straight blade separately at all the three depths of operation. Observations of man-hour requirement per hectare are presented in **Table 4**.

Table 4 shows there was lower man-hour requirement for castor stalk uprooting curved shape blade than straight, V-shape and local straight blade. The lowest man-hour requirement was 27.47 h/ha for curved shape blade at 25 cm depth of operation.

Energy Requirement

Mechanical energy required for plant uprooting and human energy required for plant uprooting, collecting and removing uprooted plants from the field was computed

Table 3 Uprooting efficiency of stalk uprooting blades at different depths

Type of blade	Depth, cm	Uprooting efficiency, %	Draft, kgf
Straight shape	25	73.6	855
	35	83.6	900
	45	86.0	1,125
V-shape	25	72.0	840
	35	80.8	880
	45	83.6	1,150
Curved shape	25	78.0	825
	35	85.2	850
	45	87.6	1,145
Local straight blade	25	66.0	880
	35	70.0	960
	45	74.0	1,200

Table 4 Man-hour requirements of stalk uprooting blades at different depths

Particulars	Depth, cm	Straight shape blade	V-shape blade	Curve shape blade	Local straight blade
Total man-hour, h/ha	25	28.17	27.93	27.47	28.47
	35	29.17	28.80	27.71	28.80
	45	29.99	29.73	28.60	30.99

Table 5 Energy requirements of different shapes of blades at different depths

Particulars	Depth, cm	Straight shape blade	V-shape blade	Curve shape blade	Local straight blade
Total energy, MJ/ha	25	928.0	899.4	842.2	956.8
	35	1,042.6	985.6	870.8	985.6
	45	1,128.7	1,100.0	1,069.6	1,158.8

for straight, V-shape, curved shape and locally used straight blade separately at all the three depths of operation. Observations of total energy requirement per hectare are presented in **Table 5**.

Table 5 shows clearly that the minimum level of energy consumption is observed in case of curved shape blade at 25 cm depth of operation for castor plant uprooting.

Cost of Operation

On the basis of actual operating hours of tractor, man hours of human labours and their prevailing rates, cost of operation for individual plant uprooter was worked out by straight line method at all the three different depths.

Table 6 illustrates that minimum cost of operation is observed in the case of curved shape blade at 25, 35 and 45 cm depths than straight shape, V-shape and local straight blade. But, curved shape blade was found the most economic with lowest cost of operation Rs.1,954.70 per hectare at 25 cm depth of operation.

Conclusions

The curved shape plant uprooting blade developed and tested at Dry farming Research Station, S. K. Nagar is better in all respect. Overall performance of the blade is better at 35 cm depth of operation.

The comparative advantages of curved shape blade over straight, V-shape and local straight shape blade were lower wheel slippage, minimum number of clogging of uprooted plants, minimum fuel consumption, higher field capacity and higher uprooting efficiency.

Curved shape blade did not face the problem of unbalancing and sliding of blade in either side of the plants during operation, which gave higher plant uprooting efficiency and effective field capacity with smooth working than straight and V-shape blade.

Table 6 Cost of operation of stalk uprooting blades at different depths

Particulars	Depth cm	Straight shape blade	V-shape blade	Curve shape blade	Local straight blade
Cost of uprooting plants, Rs/ha	25	1,925.0	1865.0	1,750.0	2,000.0
Cost of collecting plants, Rs/ha	25	204.7	204.7	204.7	204.7
Total cost, Rs/ha	25	2,129.7	2,069.7	1,954.7	2,204.7
Cost of uprooting plants, Rs/ha	35	2,175.0	2,082.5	1,810.0	2,082.5
Cost of collecting plants, Rs/ha	35	204.7	204.7	204.7	204.7
Total cost, Rs/ha	35	2,379.7	2,287.2	2,014.7	2,287.2
Cost of uprooting plants, Rs/ha	45	2,380.0	2,315.0	2,032.5	2,630.0
Cost of collecting plants, Rs/ha	45	204.7	204.7	204.7	204.7
Total cost, Rs/ha	45	2,584.7	2,519.7	2,237.2	2,834.7

REFERENCES

Adhaoo, S. H., D. S. Sonkusale, and R. B. Miskin. 1992. Design and development of animal drawn manually assisted cotton stalk puller. J. of Agric. Engg.29 (1-4): 30-34.

Anonymous. 2001. Tractor operated plant puller for cotton, castor and pigeon pea crops. AGRESCO Report Submitted by Department of Farm Machinery & Power, CAET, GAU, Junagadh.

Anonymous. 2006. http://www.Ikisan.Com./links/ap-castor History shtml:1-8.

FAO. 1977. Agricultural Services Bulletin No-12, Food and Agriculture Organization of the United Nations, Rome, (2): 161

FAO 2006. FAO Statistics Series No.163, Directorate of Statistic Division, Holuk Kasnokoglu, 54: 119.

Nichols, M. N. and C. A. Reaves 1958. Soil reaction: To sub soiling equipment, Agricultural Engineer, 39: 340-343.

Parikh. 1983. Plant puller, Agricultural Tools Bulletin-8: (1-4).

Sheikh, El-Din, Abdel, Gadir and El-Awad. 2000. Development and performance of 2-unit diggers for cotton stalks uprooting and groundnut lifting. Agricultural Mechanization in Asia, Africa and Latin America.31(4): 52-56.

Pothecarey, B. P. and R. J. Ofield. 1968. Destruction of old cotton for pest and disease control. World Crops. 20(8): 39-43.

Pannu, C. J. S., H. Singh, A. M. Chauhan, and L. N. Shukla. 1997. Development of two-row tractor operated cotton stalk up rooter. A Paper Presented in XXXII Annual Convention of Indian Society of Agricultural Engineers, held at Ludhiana Agricultural University, Ludhiana, April 16-18.

Sharma, D. N., N. K. Basal, and M. L. Jain 1993. Development and performance of manually operated cotton stalk puller. A Paper Presented in XXVIII Annual Convention and Golden Jubilee Celebration of Indian Society of Agricultural Engineers held at Central Institute of Agricultural Engineering, Bhopal, Dec. 9-11.

■■

Design, Development and Evaluation of a Peanut Sheller

by
M. A. Rostami
Scientific Board Members
Kerman Agricultural Research Center,
Tehran Road, Kerman,
P. O. Box 76175-445, IRAN
marostamy@yahoo.com

F. Azadshahraki
Scientific Board Members
Kerman Agricultural Research Center,
Tehran Road, Kerman,
P. O. Box 76175-445, IRAN

H. Najafinezhad
Scientific Board Members
Kerman Agricultural Research Center,
Tehran Road, Kerman,
P. O. Box 76175-445, IRAN

Abstract

A peanut sheller was designed and developed to separate the shell from the pod. This machine included hopper, sheller cylinder, concave, kernel platter, fan, electric motor, belt, pulley, frame, cover and bearings.

The effect of cylinder speed at four levels (4, 5, 6, 7 m/s) and the clearance between sheller cylinder and concave at 4 levels (8, 12, 16 and 20 mm) on shelling efficiency and pod damage were studied. Shelling efficiency increased as speed increased, but had no significant effect on kernel damage. The results also indicated that the shelling efficiency decreased as clearance increased. The damage rapidly decreased as clearance increased from 8 to 12 mm and gradually decreased as clearance increased from 12 to 20 mm.

Introduction

Peanut (*Archis hipogaea*) is one of the oil seeds that has 46 % oil and considerable amount of fatless dry material that is used as livestock feed with an outer shell that is suitable for fuel and crushed pallet. Since past times, the peanut has been used as a nut fruit in Iran and today it is increasing. Each peanut pod contains 1-6 kernels with a moisture content of 5-10 %. The peanut kernel must be separated from the shell to be used as nut fruit and for oil extraction (Ackali, 1996).

The Industrial Development Research Center (IDRC) began to design, develop and evaluate five types of shellers in a project in Thailand during 1981-1983. The results demonstrated that TPI shellers and revolving stone peanut shellers were not suitable for shelling peanuts (IDRC, Canada; 1983).

A peanut sheller was examined that included a main frame, hopper, a rubber tire as a sheller and wire mesh as the concave. The tire pressure and concave distance had a significant effect on the shelling efficiency, but the rate of feeding did not have this effect (IDRC, Canada; 1983).

A wood paddle sheller was investigated that had paddles rotating against a wire mesh concave. The paddles were made of wood or rubber. The shelling efficiency and the rate of pod losses were 95.4 and 5.4 %, respectively (IDRC, Canada; 1983).

Five peanut shellers; revolving stone, rubber tire, wood paddle, TPI sheller with curved teeth and TPI sheller with sharp teeth, were examined. The kernel damage, shelling efficiency and pod germination were compared with manual shelling. The average germination % with the tested machines was 87, 85, 84, 89 and 84 %, respectively, and the germination % of shelled pod with the manual method was 87 % (IDRC, Canada; 1983).

Gore and Gajendra (1990) designed a power-operated peanut sheller. The best performance of this sheller was achieved at 180 rev/min shelling cylinder speed and 18 mm concave clearance with a feed rate of 400 kg/h of pods at 13 % m.c. (d.b.). The shelling capacity, shelling efficiency and breakage were 280 kg/ha, 98.05 and 4.53 %, respectively.

Gupta et al. (1988) designed and developed a pedal operated, two person driven peanut sheller for small farmers in developing countries. The machine could shell about 160-180 kg pods/h with a shelling efficiency of 98-99 % for graded pods and < 3 % broken kernels. The power consumption was 320 W.

An experimental peanut sheller was examined by Chung et al. (1985). The peanut sheller was fed via a rotary mechanism into a shelling chamber with 8 beaters in a wire-mesh concave. The shelled kernels were separated on a vibrating sieve with an air blower. Shelling efficiency with rubber beaters was 10 % higher than with wooden ones and 2.5-5 % higher when clearance between the beaters and the drum was 15 and not 20 mm.

The effect of functional parameters of various shellers on germination % of peanut was examined by Davidson (1974). Among the studied parameters, only speed of the cylinder had significant effect on germination %.

The objective of this study was to design, develop and evaluate a peanut sheller to remove the shell from peanut pods and separate them.

Materials and Methods

A sheller was designed, developed and evaluated to separate the shell from the pods (**Figs. 1** and **2**). Designs first were drawn by Mechanical Desktop software then a sheller was built from these designs. In this sheller, a metal cylinder with stippled rubber coating revolved against a concave. An electric motor, belt and a pulley were used to turn the cylinder. The peanut pods entered the space between the cylinder and concave through a hopper. The force to cut the shell of the peanut pod resulted from the revolving sheller cylinder. The mixture of shell and kernel passed from the mesh concave and went through a steep platter.

A fan, driven by an electric motor, belt and pulley, separated the shell from kernel by the wind force. The machine parts were hopper, sheller cylinder, kernel platter, fan, electric motor, belt and pulley, frame, bearings and cover.

Design of the Component of Sheller

The sheller cylinder is one of the most important components and influences the dimensions and functions of other components. The cylinder revolves against the concave and provides enough force to cut and separate the peanut shell from the pod. The cylinder diameter and width were 35 and 40 cm, respectively. The cylinder surface was coated with stippled rubber because its polished surface did not have enough holding force to cut the shell. In this way, when the pod was placed between the cylinder and concave, enough conflict was provided.

The dimensional characteristics of the peanut pod and kernel were required in order to identify the correct dimensions and spacings of the sheller (**Table 1**). The average length and diameter of pod and kernel were used to determine the mesh of the concave as 20 mm. The clearance between cylinder and concave was variable.

A kernel platter, which was steep, was placed under the concave. This was for separating shell and kernel with the wind of the fan. In this way, the shell, with a specific weight lower than pod, left the platter by the force of the wind from the fan and the pod, with specific weight more than the shell, moved down by gravity and left the platter. The centrifugal fan was mounted on the frame with the mouthpiece attached to the front of the kernel platter.

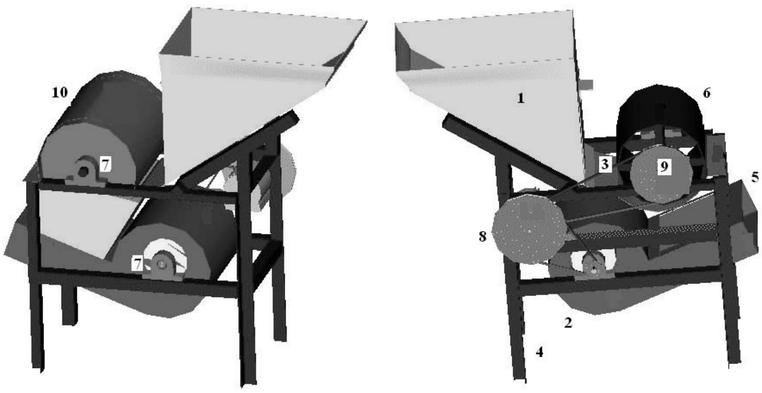
The specific weight and moisture content of the pod, kernel, and shell were identified for calculation of the required air speed for separating the peanut shell and kernel. The average results are shown in **Table 2**.

The apparent specific weight of the kernel was seven times that of the shell, and the real specific weight of the pod was nearly three times that of the shell (**Table 2**). This showed that separating the shell from the pod was easy by air flow. The air flow rate to separate the shell from the kernel was determined by trial and error.

The exit door of the hopper could

Fig. 1 The peanut pod, kernel and shell

Fig. 2 The peanut shellerdepths



1. Hopper, 2, Fan, 3. Concave, 4. Frame, 5. Kernel Platter, 6. Sheller Cylinder, 7. Bearings, 8 and 9, Belts and Pullies, 10, Cover

Fig. 3 Damaged kernels

Table 1 Some apparent characteristics of pod and kernel of peanut

		Average	Minimum	Maximum
Diameter, mm	Pod	16.38	11.7	20
Length, mm		37.77	19.5	55
Diameter, mm	Kernel	10.66	9.0	12
Length, mm		19.30	17.0	22

Table 2 The specific weight and the % of moisture of peanut pod, kernel and shell

	Pod	Kernel	Shell
Apparent specific weight, kg/m^3		596.3	82.80
Real specific weight, kg/m^3		983.1	336.70
Percent of moisture	7.38	6.5	9.07

be regulated. A 4 kW electric motor was used to drive the cylinder and fan. An inverter device was used to change the speed of cylinder and fan to evaluate the machine. The speed of the electric motor could be changed from zero to maximum.

Test and Evaluation

A factorial randomized complete block experimental design was used to evaluate the data. The parameters were four levels of linear speed of cylinder (4, 5, 6, 7 m/s) and four levels of clearance between cylinder and concave (8, 12, 16, 20 mm) in three replications. The shelling efficiency and the kernel damage % were calculated by formulas 1 and 2.

Shelling efficiency = (N1+N2) × 100/N_t .... (1)

N1 = the weight of completely shelled kernel.

N2 = the weight of completely shelled and damaged kernel.

N_t = the total weight of kernel.

Kernel damage % = (N2+N3) × 100/Nt .... (2)

N3 = the weight of semi - shelled and damaged kernel.

Results and Discussion

Analysis of variation showed that the linear speed of the cylinder and the clearance between cylinder and concave had a significant effect on the shelling efficiency with the probability of 99 %. A significant effect of linear speed and clearance was also shown by IDRC (1983). Only clearance had a significant effect on damage with the probability of 99 %. The interaction of these two factors had no significant effect on any of the parameters. Comparison of the means is shown in **Tables 3** and **4**.

Tables 3 and **4** show that shelling efficiency increased when linear speed increased because cutting force increased. Shelling efficiency increased when clearance decreased because contact of pod and cylinder increased. The kernel damage with a clearance of 8 mm was very high in comparison with other treatments, because the clearance of 8 mm was less than the 10.66 mm average peanut kernel diameter (**Table 1**). The damage rapidly decreased as clearance increased from 8 to 12 mm and gradually decreased as clearance increased from 12 to 20 mm because the clearance was more than the average of the peanut kernel diameter. The results agreed with results reported by IDRC (1983).

Table 4 showed that the best treatment was with a linear speed of 5 m/s, clearance of 12 mm, kernel damage % of 13.89 and shelling efficiency of 91.75. This treatment and the treatment with a linear speed of 6 m/s and clearance of 12 mm were in one significant group from the point of view of % of kernel damage as well as shelling efficiency. So, if the best shelling efficiency with the least rate of kernel damage was considered in the shelling process of the peanut, the linear speed of cylinder should be 5 or 6 m/s and the clearance between concave and cylinder would be 12 mm. It should be mentioned that the damage of the peanut pod is dimidiate and the crushing of pods rarely occurs, therefore, broken kernels can be used (**Fig. 3**). Unshelled pods were usually small and raw with a kernel that was faulty and of little value.

Conclusion

The peanut sheller in this study can remove the shell from peanut pods and separate them. This machine includes a hopper, sheller cylinder, concave, kernel platter, fan, electric motor, belt, pulley, frame, cover and bearings. The best shelling efficiency with the least rate of kernel damage is a linear cylinder speed of 5 or 6 m/s with a clearance between the concave and cylinder of 12 mm.

REFERENCES

Ackali, I. 1996. An approach to developing a peanut sheller. AMA. 27(3), 44-50.

Chung, D., S. Kim, and Y. Cho. 1985. Studies on the development of a peanut sheller. Inst. Agric. Mechanization, Suweon, Korea Republic.

Davidson, J. 1974. Some effects of commercial type peanut sheller design and operation on pod germination. Peanut science. 1(2), 78-81.

Gore, K. L., C. P. Gupta and S. Gajendra. 1990. Development of power operated groundnut sheller. AMA. 21(3), 38-44.

Gupta, C., G. Singh, and K. Gore. 1988. Design and operation of paddle operated peanut sheller. Conference on Agrricultural Engineering, Australia, 25-30 September1988, National conference publication No. 88-12.

IDRC, Canada. 1983. Final Report Groundnut Sheller (Thailand). Submitted to the International Development Research Center (IDRC, Canada). Availablein http://archive.idrc.ca/library/document/060359/. Accessed 18 December 2005.

Table 3 The comparison of means of interaction in different levels of linear speed and clearance on the shelling efficiency

		Linear Speed, m/sec			
		4	5	6	7
Clearance, mm	8	91.09 bc	94.56 abc	95.76 ab	97.36 a
	12	81.08 ef	91.75 bc	89.72 cd	93.06 abc
	16	79.63 fg	85.41 de	85.96 de	85.04 de
	20	63.02 j	69.61 i	73.99 hi	76.82 gh

Table 4 The comparison of means of interaction in different levels of linear speed and clearance on the % of kernel damage

		Linear Speed, m/sec			
		4	5	6	7
Clearance, mm	8	48.66 a	50.45 a	48.94 a	47.17 a
	12	16.57 bcde	13.89 cde	14.52 bcde	17.26 bcd
	16	21.33 b	19.62 bc	18.25 bcd	14.02 cde
	20	10.06 e	13.41 cde	11.48 de	14.06 cde

Factors Affecting Breaking Force Distribution of Wheat Kernel Before Milling


by
I. E. A. Elbatawi
Senior Researcher
Agricultural Engineering Research Institute,
Nadi Elsaid St., P. O. Box 256 Dokki, Giza
EGYPT
elbatawi@hotmail.com

Abstract

Three point bending tests were conducted to determine the breaking force distributions of wheat kernel. Four wheat varieties (Seds 1, Giza 168, Sohag 3 and Beni-Swaif 3) were initially studied. Seds 1 and Giza 168 were hard and soft cultivars, respectively, and cultivated in North Delta of Egypt. Sohag 3 and Beni-Swaif 3 were hard and soft cultivars, respectively, and cultivated in South Delta of Egypt. They were harvested from four locations at various dates. Breaking force was not significant to kernel width or length. However, there was a significant correlation between breaking force and kernel thickness. For all four cultivars, kernel-to-kernel breaking force distributions tended to be bimodal; one dominant peak existed around 50 N and a smaller peak around 17 N. The data showed that wheat samples could have similar average kernel breaking forces, but their breaking force distributions were quite different. In turn, head wheat yield was not related to the average breaking force of wheat kernels in a sample; however, head wheat yield was closely related to the percentage of strong kernels. The effects of growing location and harvest moisture content (HMC) on kernel-to-kernel three-point breaking force distributions (BFD) were investigated. Although, the BFDs of Sohag 3 variety (at Beni-Swaif), classified as hard wheat kernel, more closely resembled those from Giza 168 variety (at Kallein), the latest was classified as soft wheat. Thus, variety, location and soil type had an effect on breaking force distributions. The BFD patterns were affected by HMC, but were most notably affected by growing location. The distributional patterns for a variety were characteristic for a given growing location, and varied greatly across locations.

Introduction

Egyptian wheat is classified into hard and soft wheat according to its kernel hardness. Although wheat production in Egypt is 6.5 million tons/year, about 4-5 million tons/year are imported to cover the local market consumption (Ministry of Agriculture, 2004). Broken wheat kernels are sold at a much lower price than the whole grain. Wheat moisture content (MC) at harvest is one of the most important factors influencing milling quality and overall economic value. Harvest moisture content (HMC) has a dramatic impact on the gross income to a producer, due to the fact that harvest moisture content affects the field yield and milling quality. Wheat HMC has an important influence on kernel-to-kernel MC variability; this variability in turn affects kernel properties and mechanical strength distributions that ultimately determine milling quality. At higher HMC, the presence of weak, immature kernels reduces harvest yield. At low HMC, rapid moisture adsorption by low MC kernels can cause fissures, which also greatly reduces yield. Further, differences in mechanical strength distributions of kernels among growing locations could possibly explain variability in wheat yields (WY) due to growing location. Numerous studies have addressed the effects of HMC on milling quality. Kester et al. (1963) reported the highest head rice yields (HRY) at HMC between 25 % and 32 % for medium-grain 'Calrose' and short-grain 'Caloro' in California. Morse et al. (1967) showed that the maximum HRY of 'Caloro' was obtained when the HMC was between 28 % and 30 % in California. Calderwood et al. (1980) evaluated two long-grain and two medium-grain cultivars in Texas and found that the HRY reached a maximum at an intermediate harvest date and then declined. Lu et al. (1992) also reported that HRY reached a maximum and then decreased for long-grain varieties in Arkansas. Bautista and Siebenmorgen (2005) quantified variation in individual kernel MC from rice panicles at various harvest MC and grown at different locations. Also, Bautista and Siebenmorgen (2001) showed significant effects of HMC on HRY for two varieties grown in Arkansas. Peak HRY were observed at HMC that occurred near the intersection of curves quantifying the percentage of kernels with MC less than 14 % and greater than 22 %, representing, respectively, the percentage of kernels that could fissure due to rapid moisture adsorption, which increases as HMC decreases, and the percentage of immature kernels, which increases as HMC increases. Both classes of kernels reduce HRY. Physical properties of individual rice kernels at harvest influence post-harvest processing and quality. Of particular interest were kernel MC and thickness, both of which have been shown to directly impact processing performance.

Relating Kernel-to-Kernel Mechanical Property Distributions to Milling Quality

Wheat hardness is a physical property that is a manifestation of the biochemical interaction between the endosperm storage proteins and starch granules (Greenblatt et al., 1995). It is equally important to the baking and processing industries, which rely upon the differences in textural properties of hard and soft wheat when forming various food products. Numerous studies have dealt with efforts to standardize the measurement of wheat hardness, including visual inspection of crushed endosperm (Mattern, 1988), near-infrared reflectance (NIR) of ground meal (Williams and Sobering, 1986; Norris et al., 1989), force of slicing (Eckhoff et al., 1988), force and energy of crushing (Lai et al., 1985), and acoustical properties of a kernel during grinding (Massie et al., 1993). Knowledge of the physical strength properties of wheat endosperm is important because these properties are directly related to wheat hardness. Fundamental studies on single kernel physical strength have been performed on intact kernels with simplified geometry end-faced kernels with cross-sections defined by digital image analysis end-faced kernels of one cultivar subjected to crack propagation during loading-unloading cycles (Dobraszczyk, 1994).

Hardness is known to be indicative of the rate and quantity of water uptake during the tempering procedure, and although it is generally accepted that hard wheat endosperm diffuses water at a slower rate than soft wheat endosperm, the exact nature of the interaction is not well understood but appears to be affected by virtuousness and the agglomeration of starch and proteins within the endosperm (Pomeranz and Williams, 1990). Milling studies have traditionally been directed toward bulk samples of grain, with a much smaller portion of studies on single kernels, and an even smaller portion focusing on moisture within the kernel.

Although studies have been conducted on the effect of moisture on NIR hardness (Gaines and Windham, 1998), the effects on the physical strength properties of the endosperm are less prevalent. Eckhoff et al. (1988) found small but significant differences in peak force of both soft and hard wheat caused by differences in moisture content at levels of 9, 11, and 13 %. Given that an interaction between moisture content and cultivar was significant, a recommendation was made that additional testing was needed to examine the extent of this interaction. Working with five wheat varieties at three levels of moisture (10, 14, and 18 % d.b.), Kang et al. (1995) found that the slope of the stress-strain compression curve before the yield point, which they termed the modulus of deformability, decreased with increase in moisture, as did the stress and strain at yield point. In perhaps the most extensive work on the in-situ measurement of physical strength properties of wheat endosperm, Glenn et al. (1991) reported on the compressive and tensile stress properties of geometrically precise cylinders for a set of common soft and hard wheat. Researchers found that the average kernel breaking force was closely related to the percentage of fissured kernels in wheat. Lu and Siebenmorgen (1995) found that the correlation between HRY and the average maximum compressive force to crush/break rough, brown, and white rice kernels was either insignificant or of a low order of magnitude. They found that the percentage of broken kernels from milling was closely related to the percentage of kernels that did not sustain approximately a 15 N breaking force in bending. Siebenmorgen and Qin (2005) reported bimodal breaking force distributions for several long-grain varieties. They further reported a linear relationship (R^2 = 0.90) between HRY and the percentage of strong kernels, defined as kernels that withstood at least a 20 N force without breaking. These latter studies suggested a relationship between HRY and breaking force distributions.

Materials and Methods

Varieties and Locations

Four wheat varieties (Seds 1, Giza 168, Sohag 3 and Beni-Swaif 3) were initially studied. They are the most popular and preferred for Egyptian farmers and consumers. Seds 1 and Giza 168 are hard and soft cultivars, respectively, and advised to be cultivated in North Delta of Egypt. Sohag 3 and Beni-Swaif 3 are hard and soft cultivars respectively and advised to be cultivated in South Delta of Egypt. They were harvested from four locations at various dates. Seds 1 and Giza 168, were plot combine-harvested from two different fields in Kallein (Kafr-

Elsheikh) from May,1st to May, 15th on 2006 and 2007. Kallein is located in North Delta of Egypt and characterized by heavy clay soils. Sohag 3 and Beni-Swaif 3 were harvested from two different fields in Seds (Beni swaif) from April, 21st to April 30th on 2006 and 2007. Seds is located in South Delta of Egypt and has primarily silt loam soil. Immediately after harvest, samples were threshed and cleaned using a local thresher. The harvest moisture contents (HMC) of the samples were measured using an individual grain moisture tester (PM-400D, Osaka, Japan) located at the Agricultural Engineering Research Institute's laboratory, Dokki, Giza, Egypt. Ten-kg samples of each lot were sun dried by spreading the wheat on screened trays in a chamber maintained at approximately 22 ºC and 65 % relative humidity (RH). The samples were then sealed in plastic bags and stored (in the refrigerator) at 2-4 ºC until milling and mechanical property tests.

Two 500 g sub-samples from each lot were milled to determine head wheat yield (HWY). Prior to milling, the wheat kernels were shelled carefully by hand to avoid any damaged. The percentage of head wheat in each milled sample was determined using an image analyzer (hp scanjet 3400, USA).

Mechanical Properties Measured by Three Point Bending Tests

One thousand kernels were randomly selected from each location/variety/HMC lot and hulled by hand. Three-point bending tests were conducted on each wheat kernel using a digital force gauge (SHIMPO-FGC-50, Osaka, Japan) located at the Agricultural Engineering Research Institute's laboratory, Dokki, Giza, Egypt with a flat-faced loading head, having a thickness of 1.2 mm and a width of 4.5 mm. After placing a kernel across the supports, a bending test was initiated and the maximum force to failure was recorded as the breaking force. Three point bending tests were performed in a rupture mode with a cell load of 50 kg. The samples used were prepared by hand peeling wheat hull to minimize any mechanical damages to wheat kernels. In the experiments, 300 wheat kernels were randomly picked for mechanical property measurement. The mechanical properties of the fissured wheat kernels from the samples stored in the equilibrium moisture content chamber were measured similarly. The force and probe height of the instrument were calibrated as per the manufacturer's instruction to ensure an accurate force and deformation. For bending tests, the instrument deflection was also compensated in order to maintain an accurate deformation of the beam. From a bending force-deformation curve, the peak bending force, deformation at breakage, bending strength (also known as flexural strength), apparent modulus of elasticity, and fracture energy were obtained. The terms were defined as follows (ASAE, 2001):

1. The ultimate shear strength (stress) is determined by:

   $\tau = F / 2A$

   where **τ** is shear stress, Pa, **F** is applied fracture force, N and **A** is initial cross-sectional area, m^2 .
2. Maximum bending stress a material can sustain before it is ruptured by a flexural load. It can be calculated by:

   $\sigma = FLC / 4I$

   where **σ** is bending strength, Pa, **F** is peak bending force, N, *L* is distance between the two supports (also known as beam span), m, ***C*** is distance from the neutral axis to the outer layer of the rice kernel, m (for a wheat kernel, **C = D/2**), and *I* is moment of inertia, m^4. If the cross section area perpendicular to the longitudinal axis of a wheat kernel is assumed to be an ellipse, *I* can be calculated as $I = 0.069B*D^3$ where *B* is the major diameter of the ellipse (width of the wheat kernel) and *D* is the minor diameter of the ellipse (thickness of the wheat kernel).
3. The modulus of elasticity is calculated from the first loading cycle. It can be calculated for three-point bending by:

   $E = FL^3 / 48I\delta$

   where *E* is apparent modulus of elasticity, Pa and is δ deformation, m.
4. The energy required to rupture a material. It is the area under the force-deformation curve up to the point of fracture.

   $G = \int Fd\,\delta / A$

   where *G* is fracture energy, J/m^2, $\int Fd\,\delta$: is the area under the force-deformation curve, which can be obtained by any software of integration capability, *A* is the area of fracture surface, which can be calculated as $A = \pi\ BD /4$ assuming the fracture surface is an ellipse and the breakage surface bisects the rice kernel perpendicularly to the longitudinal axis.

Tempering

Tempering, which is the addition of water to wheat before milling, is a routine procedure that enhances the efficiency of flour extraction. Its purpose is essentially to wheat hardness, a physical property that is a manifestation of the biochemical interaction between the endosperm storage proteins and starch granules (Greenwell and Schofield, 1986). Tempering experiments were performed to recover the whole kernel percentage after sun drying. Tempering has been shown to be an effective way to preserve head wheat yield that would otherwise be reduced for an extended drying duration.

In Egypt, wheat is typically harvested at moisture contents (MC) ranging from 13 % to 22 %, and subsequently dried to approximately 13 % for safe long-term storage.

Wheat is tempered (before the start of grinding) the process in which moisture is added. Tempering aids the separation of the bran from the endosperm and helps to provide constant controlled amount of moisture and temperature throughout milling. The percentage of moisture, length of soaking, time and temperature are three important factors in tempering when held in a bin for 12 hours. The outer layers of wheat tend to be brittle and tempering toughens the bran coat to permit more complete separation of the endosperm so that floury particles break more freely in milling.

Results and Discussion

Fig. 1 shows a typical wheat kernel force-deformation curve measured during a three-point bending test. As shown in the figure, deformation was linearly related to applied load up to the break point. A significant drop in applied force indicated the break point; this force was recorded as the breaking force.

Effect of harvest moisture contents on breaking force distribution

The average breaking force ranged from 20 to 50 N over the harvest moisture content range from 15.4 % to 22.3 % of the samples. There were inconsistent trends and large levels of variability in average breaking force values across harvest moisture contents HMC. Some varieties showed general trends of increasing average breaking force as HMC decreased, while others showed the opposite trend; this may have depended some on the scope of the HMC range for a given variety.

Fig. 2 shows the breaking force distributions BFD for Seds 1 samples with high (22.1 %), medium (19.3 %), and low (16.4 %) HMC harvested at Kallein. The peak breaking force mode to shift to greater breaking forces as harvest moisture content (HMC) decreased. This would indicate that the overall average strength of kernels increased as HMC decreased. However, as the MC decreases to critically low levels, kernels become susceptible to fissuring by rapid moisture adsorption, which can drastically lower kernel breaking force. Because Seds 1 variety was classified as hard wheat, the maximum breaking force was found to be 50 N.

Fig. 3 shows selected BFDs for Giza 168 lots harvested from Kallein samples with high (21.6 %), medium (18.4 %), and low (15.9 %) harvest moisture content. The BFD showed a much different pattern than those of Seds 1. The BFD for Seds 1 variety were higher than of Giza 168 variety. The maximum BFD for Seds 1 were about 50 N and it was about 28N for Giza 168 as shown in **Figs. 2** and **3**. This significant difference in BFD could have ramification in milling quality as it is hypothesized that kernels with low breaking forces, resulting from either being thin due to immaturity or fissured due to moisture adsorption, will be prone to breaking during milling.

Fig. 4 shows selected BFD for samples of Sohag 3 variety cultivated in Beni-Swaif with high (21.5 %), medium (18.7 %), and low (16.1 %) harvest moisture contents. Although, the BFD more closely resembled those from Giza 168 variety at Kallein (**Fig. 3**) but Sohag 3 variety classified as hard wheat. That means, variety, location and soil type having effect on BFD. As HMC decreased, the distributions became more uniform, transforming into a bi-modal and then practically a single-modal distribution. The occurrence of moisture adsorption fissuring due to weather conditions could also have played a role in this inconsistency. The distributions for Sohag 3 variety in figure 4, the distribution for the sample harvested at 16.1 % MC produced a primary mode at a much lower breaking force than the samples at higher harvest moisture contents.

Fig. 5 shows selected BFD for samples of Beni-Swaif 3 variety cultivated in Beni-Swaif with high (22.3 %), medium (17.8 %), and low (15.4 %) harvest moisture contents. In general, samples with harvest moisture contents greater than 20 % produced a bi-modal breaking force distribution.

Effect of average breaking force on wheat yield

Fig. 6 indicates the relationship between harvest wheat yield (HWY) and the average breaking force of wheat kernels for all samples. For samples from Kallein, there was no relationship between HWY and average breaking force and in that HWY did not dramatically vary over the range of average breaking forces. The samples from Beni-Swaif generally showed a little relationship between HWY and average breaking force. The little relationship between HWY and average breaking force for Beni-Swaif samples may be related to wheat variety which resist climate conditions.

Effect of Strong Kernels on Wheat Yield Percentage

There was a stronger relationship between head wheat yield (HWY) and the percentage of kernels that withstood a certain breaking force. This breaking force level varied depending on the wheat variety. A significant relationship between HWY and the percentage of kernels that withstood a breaking force greater than 25 N.

Each point was generated from a 300 kernel wheat sample. Using the 25 N breaking force as the level that separated strong from weak kernels, the percentage of strong kernels for each sample was calculated. **Fig. 7** indicates the relationships between HWY and the percentage of strong kernels for each location/variety/HMC lot. **Fig. 7** also shows a lack of correlation among varieties. However, a potential reason for this lack of correlation is the choice of force level used to differentiate strong from weak kernels. Strong kernels are defined as those kernels that withstood more than a 25 N

Fig. 1 Typical force deformation curve for wheat kernel under three-point bending

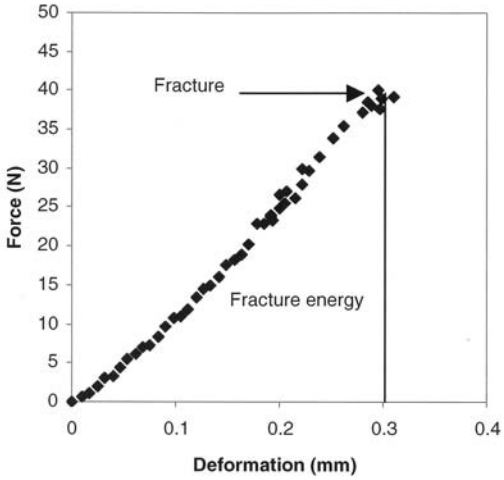


Fig. 2 Kernel breaking force frequency distributions at selected harvest moisture contents (HMC) in 2006 for Seds 1 variety

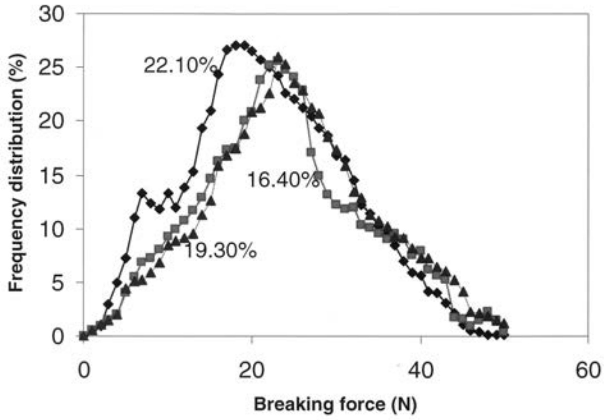


Fig. 3 Kernel breaking force frequency distributions at selected harvest moisture contents (HMC) in 2006 for Giza 168 variety

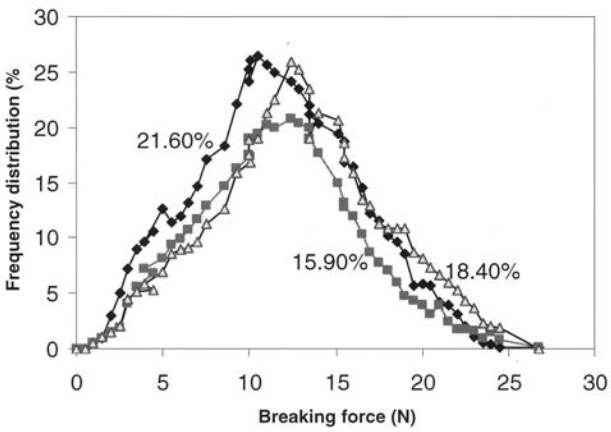


Fig. 4 Kernel breaking force frequency distributions at selected harvest moisture contents (HMC) in 2006 for Sohag 3 variety

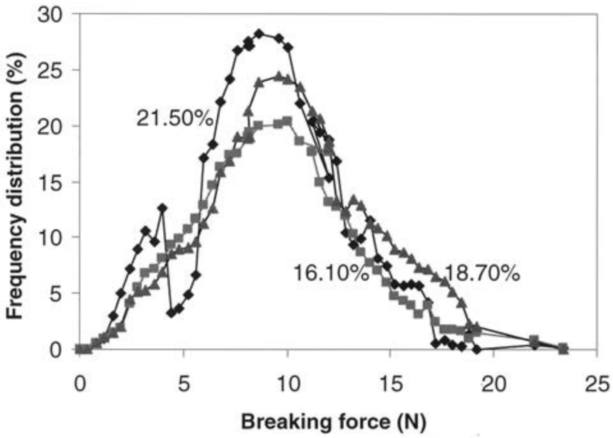


Fig. 5 Kernel breaking force frequency distributions at selected harvest moisture contents (HMC) in 2006 for Beni-Swaif 3 variety

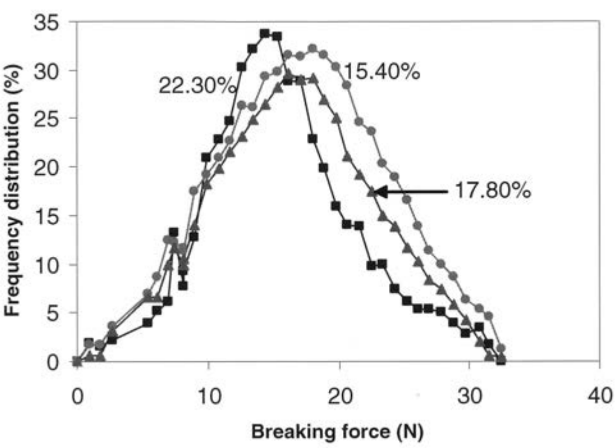
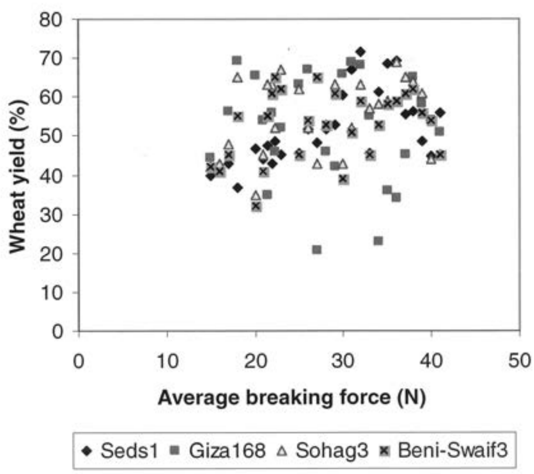


Fig. 6 Correlation of wheat yield to average breaking force for samples harvested in 2006 for Kallein and Beni-Swaif fields



force in a bending test. Head wheat yield was better correlated with the strong kernel percentages at Kallein and Beni-Swaif.

In summary, the breaking force distributions, measured across a range of HMC and growing locations, did not reveal a consistent demarcation between high and low kernel breaking force modal populations. Furthermore, the magnitude of this demarcation force was dependent on the production location, there by precluding the use of a universal force level to differentiate weak from strong kernels.

Breaking Force Versus Physical Dimensions

Fig. 8 shows the wheat kernel thickness, width, and length distributions for the four varieties tested. The relationships between breaking force and physical dimensions (length, thickness, and width) of all varieties are shown. Correlations between length or width and the breaking force of rice kernels were weak (average R2 for the four cultivars was 0.27 for length and 0.25 for width). However, the correlation between kernel thickness and breaking force was much stronger (R 2 was 0.54 for Seds 1, 0.49 for Giza 168, 0.47 for Sohag 3 and 0.43 for Beni-Swaif 3). It is clear that thicker kernels tended to have greater breaking forces, especially for Seds 1.

It is clear that the percentage of weak and strong kernels strongly depended on kernel thickness; in turn, thickness distributions would be expected to change with harvest moisture content. Wheat kernels in the thickness ranges of 1.2-1.4 mm were almost all weak kernels. However, the percentage of weak kernels decreased dramatically when thickness was greater than 1.5 mm.

Fig. 7 Correlation of head wheat yield to percentage of strong kernels for all samples harvested in 2006 from Kallein and Beni-Swaif fields. Each point represents an average of 300 wheat kernels.

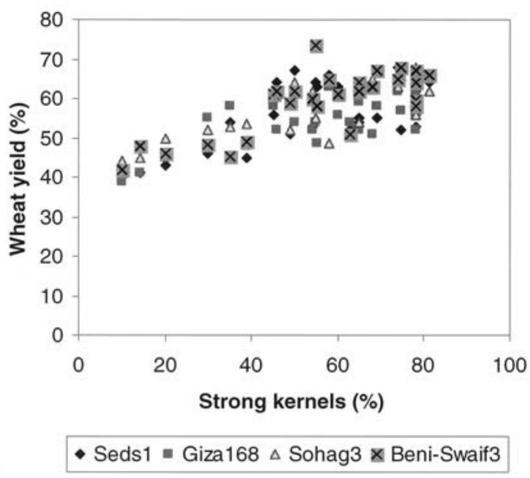


Fig. 8 Physical dimensions vs. breaking force for Seds 1 variety kernels as an example for strong kernel

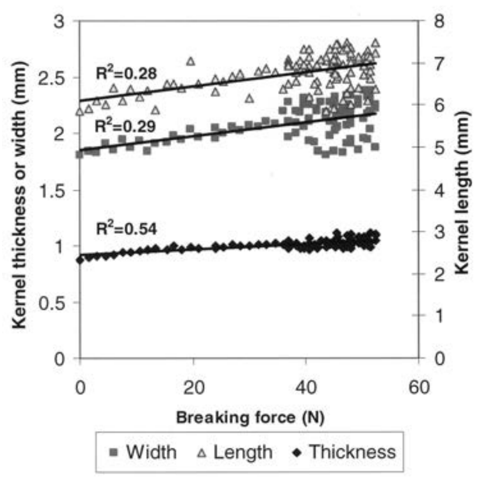


Fig. 9 The apparent modulus of elasticity of wheat kernels at different moisture contents. Each point represents an average of 300 wheat kernels.

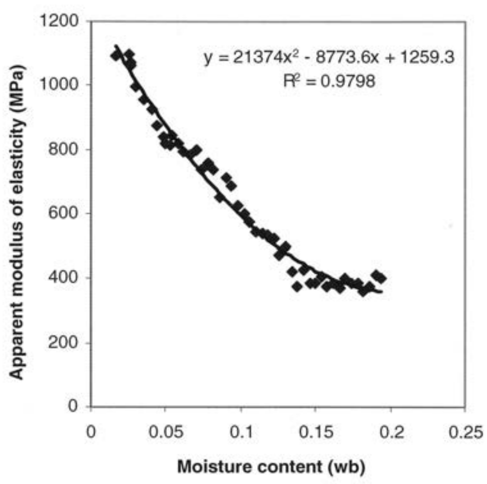
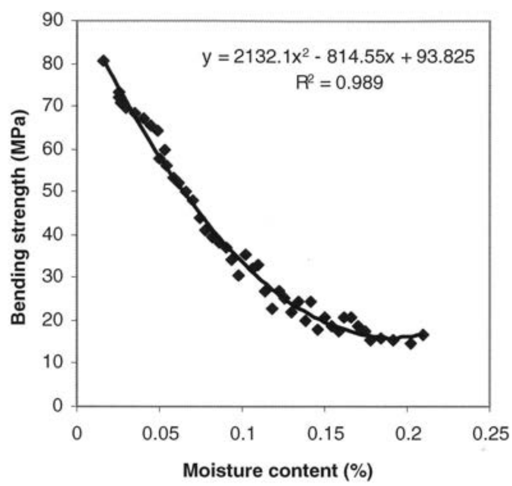


Fig. 10 The bending strength of the wheat kernels at different moisture contents. Each point represents an average of 300 wheat kernels.



Mechanical Properties of Wheat Kernels as Affected by Moisture Content

Apparent Modulus of Elasticity

The apparent modulus of elasticity vs. moisture content curve is shown in **Fig. 9**. The relationship between the modulus of elasticity and moisture contents could be closely approximated by a quadratic relationship as follows:

$E = 21374MC^2 - 8773.6MC + 1259.3$ ($R^2 = 0.98$)

where E is the apparent modulus of elasticity in MPa and MC is moisture content of wheat kernels in decimal w.b.

As a general trend, the apparent modulus of elasticity decreased as moisture content increased, but the modulus decreased faster at lower moisture contents (11.3-17.4 %) than higher moisture contents (17.4-21.1 %).

Bending Strength

Shown in **Fig. 10** is the bending strength versus moisture content curve. It can be seen that bending strength of the wheat kernels increased with decreasing moisture content during sun drying. This suggests that the wheat kernels became stronger and stronger along the sun drying process with the removal of moisture. The trend of the bending strength versus moisture contents could also be described by a quadratic equation:

$s = 2132.1MC^2 - 814.55MC + 93.825$ ($R^2 = 0.99$)

where s is the bending strength in MPa and MC is moisture content in decimal w.b. The bending strength ranged from 10.4 MPa to 60.3 MPa when moisture content ranged from 21.1 % to 6.3 %.

Fracture Energy

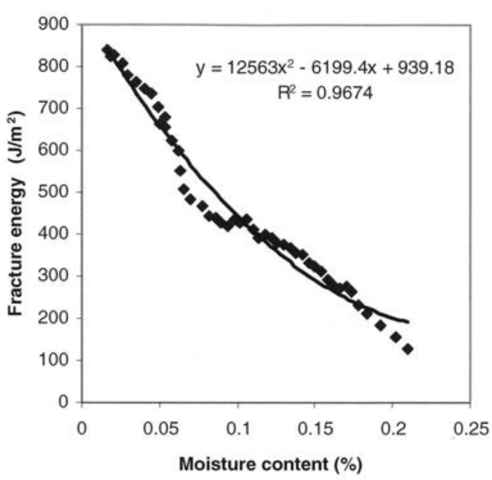
Fig. 11 is the fracture energy as a function of moisture content for all dried samples. Since fracture energy is an indicator of the toughness of a material, the higher the fracture energy is, the more difficult it is to break the material. The trend of the fracture energy appeared more complex than that of the bending strength, as indicated in **Fig. 10**. The fracture energy increased initially as moisture content decreased from the initial value before reaching a plateau in the moisture content range and increased again as moisture content decreased. The trend of the fracture energy versus moisture contents could also be described by the following quadratic equation:

$FE = 12563\ MC^2 - 6199.4\ MC + 939.18$ ($R^2 = 0.97$)

where FE is the fracture energy in J/m^2 and MC is moisture content in decimal w.b.

According to its definition, fracture energy is the area under the force-deformation curve up to the breakage point. Because of this, the trend of fracture energy might resemble that of the relationship between the deformation at breakage and moisture content. The deformation at breakage decreased with the decrease of moisture content during drying.

Fig. 11 The fracture energy of the wheat kernels at different moisture contents. Each point represents an average of 300 wheat kernels



Conclusions

The breaking force distributions (BFD) of wheat kernels of Seds 1, Giza 168, Sohag 3 and Beni-Swaif 3 wheat samples were measured using a three-point bending test. Samples of head wheat yield was directly related to the percentage of strong kernels within a sample. The breaking forces of wheat kernels were not significantly related to kernel width or length, but were related to kernel thickness. The significant difference in BFD could have ramification in milling quality as it is hypothesized that kernels with low breaking forces, resulting from either being thin due to immaturity or fissured due to moisture adsorption, will be prone to breaking during milling. It is clear that thicker kernels tended to have greater breaking forces.

The apparent modulus of elasticity, bending strength and fracture energy of the wheat kernels increased with the decrease of moisture content. The wheat kernels became stronger (as reflected by the bending strength) and tougher (as reflected by the fracture energy) during drying. The bending strength of the wheat kernels increased with decreasing moisture content. This suggests that the wheat kernels became stronger and stronger along the sun drying process with the removal of moisture. The fracture energy increased initially as moisture content decreased from the initial value before reaching a plateau in the moisture content range and increased again as moisture content decreased.

The effects of growing location and harvest moisture content (HMC) on kernel-to-kernel three-point breaking force distributions (BFD) were investigated. The BFD patterns were affected by HMC, but were most notably affected by growing location. The distributional patterns for a variety were characteristic for a given growing location, and varied greatly across locations. The strongest correlations between wheat yield and the percentage of strong kernels were found for location/variety/HMC lots. A significant relationship between HWY and the percentage of kernels that withstood a breaking force greater than 25 N.

Although the BFD of Sohag 3 variety (at Beni-Swaif), classified as hard wheat kernel, more closely resembled those from Giza 168 variety (at Kallein) the latter was classified as soft wheat. Thus, variety, location and soil type had an effect on breaking force distributions.

REFERENCES

ASAE, 2001. ASAE Standards S459: Shear and three point bending test of animal bone. St. Joseph, MI, pp. 581

Lu, R. and T. J. Siebenmorgen. 1995. Correlation of head rice yield to selected physical and mechanical properties of rice kernels. Trans. ASAE 38(3): 889-894.

Bautista, R. C. and T. J. Siebenmorgen. 2001. Rice kernel properties affecting milling quality at harvest. In Rice Research Studies 2000, eds. R. J. Norman and J.-F. Meullenet. Research series 485, University of Arkansas. Fayetteville.

Bautista, R. C. and T. J. Siebenmorgen. 2005. Individual rice kernel moisture content variability trends. Applied Engineering in Agriculture 21(4): 637-643.

Calderwood, D. L., C. N. Bollich, and J. E. Scott. 1980. Field drying of rough rice: Effect on grain yield, milling quality, and energy saved. Agronomy J. 70(4): 649-653.

Dobraszczyk, B. J. 1994. Fracture mechanics of vitreous and mealy wheat endosperm. J. Cereal Sci. 19(3): 273-282.

Eckhoff, S. R., W. A. Supak, and A. B. Davis. 1988. A rapid single kernel wheat hardness tester. Cereal Chem. 65(6): 503-508.

Gaines, C. S. and W. R. Windham. 1998. Effect of wheat moisture content on meal apparent particle size and hardness scores determined by near-infrared reflectance spectroscopy. Cereal Chem. 75(3): 386-391.

Glenn, G. M., F. L. Younce, and M. J. Pitts. 1991. Fundamental physical properties characterizing the hardness of wheat endosperm. J. Cereal Sci. 13(2): 179-194.

Greenblatt, G. A., A. D. Bettge, and C. F. Morris. 1995. The relationship between endosperm texture, and the occurrence of friable and bound polar lipids on wheat starch. Cereal Chem. 72(2): 172-176.

Kester, E. B., H. C. Lukens, R. E. Ferrel, A. Mohammed, and D. C. Finfrock. 1963. Influences of maturity on properties of western rice. Cereal Chem. 40(4): 323-326.

Kang, Y. S., C. K. Spillman, J. L. Steele, and D. S. Chung. 1995. Mechanical properties of wheat. Transactions of the ASAE 38(2): 573-578.

Lai, F. S., R. Rousser, D. Brabec, and Y. Pomeranz. 1985. Determination of hardness in wheat mixtures. II. Apparatus for automated measurement of hardness of single kernels. Cereal Chem. 62(3): 178-184.

Lu, R., T. J. Siebenmorgen, T. H. Dilday, and T. A. Costello. 1992. Modeling long- grain rice milling quality and yield during the harvest season. Transactions of the ASAE 35(6): 1905-1913.

Massie, D. R., D. C. Slaughter, J. A. Abbott, and W. R. Hruschka. 1993. Acoustic single-kernel wheat hardness. Transactions of the ASAE 36(5): 1393-1398.

Mattern, P. J. 1988. Wheat hardness: A microscopic classification of individual grains. Cereal Chem. 65(4): 312-315.

Ministry of Agriculture 2003. Wheat Production in Egypt. Technical report No. 16. Cairo, Egypt.

Morse, M. D., J. H. Lindt, E. A. Oelke, M. D. Brandon, and R. E. Curley. 1967. The effect of grain moisture at time of harvest on yield and milling quality of rice. Rice J. 70(11): 16-20.

Norris, K. H., W. R. Hruschka, M. M. Bean, and D. C. Slaughter. 1989. A definition of wheat hardness using near infrared reflectance spectroscopy. Cereal Foods World 34(9): 696-705.

Pomeranz, Y. and P. C. Williams. 1990. Wheat hardness: Its genetic, structural, and biochemical background, measurement, and significance. In Advances in Cereal Science and Technology, Vol.10: 471-557. St. Paul, Minn.: The American Association of Cereal Chemists.

Pomeranz, Y., C. R. Martin, R. Rousser, D. Brabec, and F. S. Lai. 1988. Wheat hardness determined by a single kernel compression instrument with semi-automated feeder. Cereal Chem. 65(2): 86-94.

Siebenmorgen, T. J. and G. Qin. 2005. Relating rice kernel breaking force distributions to milling quality. Transactions of the ASAE 48(1): 223-228.

Williams, P. C. and D. C. Sobering. 1986. Attempts at standardization of hardness testing of wheat: II. The near-infrared reflectance method. Cereal Foods World 31(6): 417-420.

Windham, W. R., C. S. Gaines, and R. G. Leffler. 1993. Effect of wheat moisture content on hardness scores determined by near-infrared reflectance and on hardness score standardization. Cereal Chem. 70(6): 662-666. VOL. 43(2): 365-373.

■■

Development of Tillage Machinery for Conservation Agriculture in Bangladesh

by

K. C. Roy
Director
Wheat Research Centre
Bangladesh Agricultural Research Institute
Nashipur, Dinajpur
BANGLADESH
E-mail : drkcroy@yahoo.com

M. E. Haque
Program Manager
CIMMYT, Dhaka
BANGLADESH

Scott Justice
Kathmandu,
NEPAL

Israil Hossain
Senior Scientific Officer
Wheat Research Centre
Nashipur, Dinajpur
BANGLADESH

C. A. Meisner
Cornell Univ. Adjunct Prof.
BANGLADESH

Abstract

In conservation agriculture composition, structure and natural biodiversity of soil is altered as little as possible to reduce soil erosion and compaction. Farmers drastically reduce tillage and keep a protective soil cover of leaves, stems and stalks to protect the soil from heat, wind and rain. As less or no tillage is practiced, the cost of labour, machinery and fuel is reduced. A power tiller operated zero till drill and seedbed planter have been designed and developed for introducing conservation agriculture in Bangladesh, which is new to the country. These were fabricated with locally available materials like mild steel angle, mild steel bar, mild steel sheet, ball bearing etc. These were operated by 9 to 12 kW power tiller. Field demonstrations were conducted to determine their capacity, effectiveness of sowing, planting and fertilizer placement cost, and yield. In zero till sowing, the average yield of wheat was 13 % more than the conventional method whereas that in maize was 15 % less. The sowing/planting cost in zero tillage system was 83 % and 89 % less than the conventional system in wheat and maize, respectively. In bed plating system, the yields of wheat, mungbean and maize were 24, 33 and 33 % more than the conventional system. The cost of planting in the seedbed system was 59 % less than the conventional system.

Introduction

Bangladesh has an area of 147,570 sq. km of which 8.29 mha is cultivable. Out of the cultivable land, 7.19 mha, i.e. 87 % is cultivated (BBS, 2002). The average farm size is only 0.68 ha. About 80 % of holdings has farm size between 0.20 and 1.0 ha and 2.52 % above 3 ha. Because of fragmented land, the two-wheel tractor, called power tiller (PT), became popular for tillage operation. In the traditional tillage system, the bullock drawn country plough is used for seed bed preparation. In this system, land preparation can not be completed in time to keep pace with increased cropping intensity. As a result, many lands remained fallow. Almost all the crops are sown by hand broadcasting. Therefore, germination is hampered, seed requirement is increased, and desired plant population can not be ensured. At present, research and development work is conducted on power tiller operated seeder for wheat, maize, pulses, oilseeds and jute. Survey reveals that the use of PTs for tillage operation in Bangladesh was 11 % of total cultivated area in 1991, which has increased to 17 % in 1992, 55 % in 1995 and 75 % in 2003 (Saunders, 1990, 1991; Meisner, 1992, 1996, 1999 and 2001). It has a great potential for use in different crop establishment and agricultural operation through the development of new accessories. At present about 300,000 PTs are being operated in the country. In addition to tillage operation, PTs are also used for water pumping for irrigation, threshing, paddy husking and rural transportation.

Conservation agriculture refers to

several practices, which permit the management of the soil for agrarian uses, altering its composition, structure and natural biodiversity as little as possible and defending it from degradation processes like soil erosion and compaction. In general, conservation agriculture includes any practice which reduces, changes or eliminates soil tillage and avoids residue burning to maintain enough surface residue throughout the year (ECAF, undated). Through conservation agriculture, scientists are looking for a strategy to hold back the desert, raise yields, increase incomes and allow farmers to shorten fallow periods (ECAF, 2002). It means that farmers drastically reduce tillage and keep a protective soil cover of leaves, stems and stalks of previous crops in order to protect the soil surface from heat, wind and rain. It also keeps the soil cooler and reduces moisture loss by evaporation. When less tillage is practiced, cost of labour, machinery and fuel is reduced (Washington Free Press, 2001). Among all the agricultural operations, soil tillage consumes the most energy and pollutes air. If tillage is not practiced, 30 to 40 % time, labour and fuel costs can be saved. Use of fertilizer and herbicides can be reduced over the years if conservation agriculture is practiced.

Zero till saves planting time, fuel and water, improves efficiency of fertilizers, reduces weed density, reduces the wear and tear of tractors, improves soil health, promotes residue management and helps reduce air pollution (Hobbs and Mehla, 2003). Furthermore, it could increase farmers' profit by US $ 55 to 75 per ha (Gupta et al., 2003). To overcome the problem and help the farmer to establish crops in time, with less cost, zero tillage or no tillage, planting seed with minimum soil disturbance is one of the best alternative options.

Crop establishment using bed planting system is a new technique in the farming system of South Asia. While there are thousands of hectares being sown to wheat in Pakistan and India, very few hectares have been sown in the Eastern Gangetic Plains of South Asia, due to lack of machinery for smaller land holdings common for this area (Gupta et al., 2002). Generally farmers grow potatos in ridge and furrow method and some vegetables in beds. Bed planting system for wheat was originally developed in Mexico's Yaqui Valley, where more than 90 % of farmers had adopted the practice. In Northwest Mexico, high yielding irrigated wheat is commonly rotated with soybean, and the farmers have increased crop yields dramatically by using this practice in the last decade (Meisner et al., 1992). Raised bed cultivation facilitates more optimum planting time by providing timelier field access because of better drainage. Additionally, once the beds are established there are new opportunities to reduce crop turn-around time by re-using the same bed without tillage (Sayre, 2003). This system has many advantages such as reducing the seed rate, increasing crop yield, requiring less water, imparting higher nitrogen use efficiency, and reducing crop lodging over the conventional tillage/sowing systems (Hobbs et al., 1997). Specific research findings show that the benefits of the raised bed planting systems with furrow irrigation compared to conventional flat planting with flood irrigation, water saving of 30 % can be achieved by changing from flood to furrow irrigation. It also eliminates the formation of crust on soil surface (Fahong et al., 2003).

The objective of this paper was to develop and evaluate the performance of two power tillers for conservation agriculture in Bangladesh.

Materials and Methods

PT-operated minimum/reduced tiller seeder is used for sowing paddy and wheat and pulses. in wet soils (up to 30 % m.c.) just after the harvest of rice, thus, avoiding late planting that causes 1.33 % yield loss of wheat per day of late planting after 30 November (Saunders, 1988). It places seeds at a uniform depth and provides very fine soil tilt that ensures germination. It also reduces weed problems associated with zero-till and surface seeded wheat. Meisner et al. (2001) reported 5-year trials in Bangladesh and concluded that there is no better resource conservation technology (RCT) than this seeder.

A minimum tillage seeder can be converted to strip tillage seeder by removing 50 % tines from the rotary tillers. In this system, a 400 to 600 mm wide planting strip is tilled by the rotary tines to place seeds. The outcome of this seeder research is not extensive but is very promising. Nearly all the benefits of minimum tillage seeder are present (understandably except for weed control) with the added bonuses of 15 % or more increased field efficiency, 20 % less diesel, and residual water savings due to less tilling.

Two types of power tiller operated planting machinery used in the present study are zero till drill and bed planter. Both are suitable

Table 1 Soil condition of zero till drill operation

Soil type	Soil moisture, %	Depth of planting, mm		Rice residue density, g/m^2
		Wheat	Maize	
Sandy loam	25	30-40	40-50	140
Clay loam	28	30-40	40-50	155
Clay soil	30	30-40	40-50	150

for sowing/planting seed after monsoon paddy-harvested land. While harvesting paddy, farmers generally leave 100 to 250 mm straw on the ground. At that time soil is not very dry and weeds infestation are comparatively low. **Table 1** shows the soil type, moisture content, depth of planting and rice-residue density for wheat and paddy fields. The machines performed better in plain soil with rectangular shape and size land.

Zero Till Seed Drill

A power tiller operated zero till seed drill was designed and fabricated with locally available materials such as mild steel (M.S.) angle, M.S. bar, M.S. sheet and ball bearing. The main functional parts of the drill was toolbar frame, seed and fertilizer metering device, seed and fertilizer box, furrow opener (inverted 'T' opener), depth control wheel and chain with sprocket for power transmission from the axle of the PT wheel (**Fig. 1**). The performance evaluation of the zero till drill was done in the farmers' field at different locations of Bangladesh from 1999 to 2002. The necessary improvements have been made on the basis of feedback from farmers, operators, manufacturers and field observations. The testing of the drill was done by attaching it to a 9 to 12 kW PT. The wheat variety Protiva was used for testing the seed drill. Di Ammonium Phosphate (DAP) fertilizer was used as basal for wheat cultivation. The planting depth and seed covering mechanism were adjusted during the field operations. The agronomic data like depth of seeding, crop establishment and grain yield were collected during the field tests.

Seed Calibration

Transparent polyethylene bags were tagged with each of the four seed delivery tubes. The zero till drill was operated on a pre - measured 20 m travel distance on a concrete floor with a sowing width of 800 mm, thus providing a 16 m2 area. After every 20 m linear distance run, collected seeds through tubes were weighed separately and the total seed weight was noted. This method was repeated by acceleration and deceleration of the lever of the seed meter until the desired seed rate was obtained. Since the seed metering device is connected by a chain-sprocket arrangement to the axle of power tiller wheel, the speed of the tiller should not be a factor in calibration, unless there is wheel slippage.

Turning loss is the time lost during turning of the power tiller at the end of every pass. The time loss was recorded by a stop watch. Wheel slippage is the travel reduction of the tiller during operation in the field. It is generally expressed as percentage and is calculated as follows:

$$S = \frac{l1 - l2}{l1} \times 100$$

where S = wheel slippage (%), l1= ten revolution distance on concrete floor (mm) and l2= ten revolution distance in the field (mm).

Bed Planter

A toolbar frame was fabricated with locally available mild steel materials. A pair of shovel type furrow openers was made and fitted to the tool bar frame. A bed shaper was also fabricated and attached behind the furrow opener. The shape of the bed was trapezoidal with 300 mm top and 700 mm bottom width. A seed box with a metering device was also attached to the frame. The seed-metering device was operated by a chain sprocket mechanism, which transmitted power from the wheelbase of the PT. The bed planter was hitched to the power tiller. It was tested at the experimental farm of Wheat Research Centre, Nashipur and at the farmers' field

Fig. 1 Photographic view of the two-wheel tractor operated zero till drill with main functional components

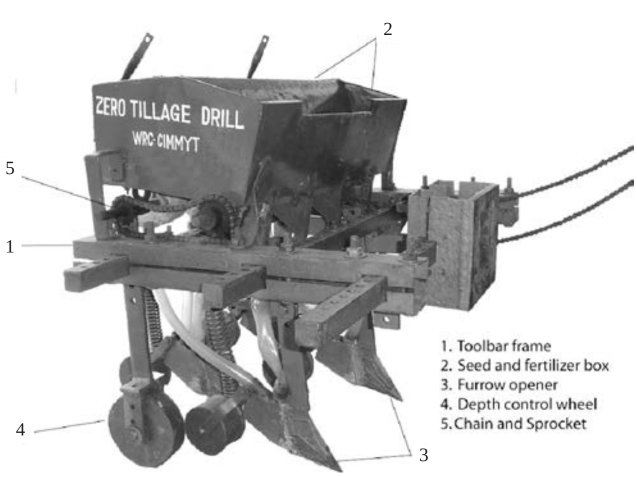


Fig. 2 Photographic view of the power tiller operated bed planter

in different areas for wheat, mungbean and maize sowing/planting during 2001-04. **Fig. 2** shows a photographic view of the PT operated bed planter. It was operated in tilled soils. There were two lines per bed for wheat, two for mungbean and one for maize.

The bed planter had one operator. The quality of bed formation and planting depended on the skill of the operator. The furrow opener angle and shaper position played an important role in the successful operation of the planter. To maintain equal shape, size and straight bed, the furrow opener angle and wing radius of curvature was required to be accurate for both the furrow openers. These should be placed just behind the wheel of the power tiller for easy operation. Radius of curvature of the furrow opener wing was 580 mm. Furrow to furrow distance was 700 mm. During the test, data on depth of seed placement, travel speed, effective field capacity, field efficiency, fuel consumption, number of plants /m^2 and yield were collected. Cost was calculated according to the farm machinery utilization method (Anonymous, 1991).

Results and Discussion

Zero Till Drill

On the basis of collected data and field observations since 1999, results of the zero till drill are presented. It facilitated quicker planting operation immediately after rice harvest. Generally farmers take 10 to 15 days for land preparation before sowing wheat with their traditional cultivation system. **Table 2** shows the field efficiency parameters of zero till drill for wheat and maize from the demonstration trials. It has been observed during the trial that performance of the zero till drill differed between wheat and maize. Fuel consumption, wheel slippage, effective field capacity and field efficiency were higher in wheat than in maize. However, only speed of operation for maize was higher than for wheat. It was also found that slower speed was comparatively better for seed placement in the opening slit. Depth of maize planting was higher than that of wheat seeding which influenced the performance of the zero till drill. Density of average rice residue on the soil surface was 150 g/m^2 before sowing/planting wheat and maize.

Seed and Fertilizer Application

In untilled land, the power tiller operated zero till drill could apply seed and fertilizer in one pass. The seed and fertilizer were applied in 30 to 40 mm depth in the same slit. The applied seed rates of wheat and maize were 120 and 20 kg per ha, respectively (**Table 3**). Fluted type gravity flow seed metering device was used for both wheat and maize sowing. The wheat seed rate was 40 % less compared to the conventional method, but the maize seed rate was the same as conventional. About 7 to 8 % gap filling and about 10 % thinning were needed for maize due to the missing seed dropping for uneven seed size. The doses of basal fertilizer (Di Ammonium Phosphate) rates for wheat and maize were 180 and 230 kg/ha, respectively. The plant population of wheat was 20 % higher compared to the conventional method. During the field monitoring, less (80 %) cutworm attack was observed in the zero till maize field compared to the conventional method.

Soil Moisture Content vs. Wheel Slippage Relationship

Soil moisture content is an important factor for efficient operation of the zero till drill. It was tested in a wide range of soil moisture contents to determine the optimum moisture content for efficient operation of the machine. The optimum moisture content for its operation was about 35 %. However, the soil moisture content above this value decreased the field efficiency due to higher wheel slippage (**Fig. 3**).

Yield and Sowing/Planting Cost

The PT operated zero till cum fertilizer drills have been demonstrated in different farmers' fields. The yields and sowing/planting cost of wheat and maize in the zero tillage system and conventional system are shown in **Table 4**. The yield of wheat in zero till method varied from place to place due to variation in land type, soil moisture, fertilizer application and weed management. Round up herbicide was applied @ 35 ml per 10 litres for controlling weeds. The soil contained 25 to 30 % soil moisture with crop residue 150 g/m^2 during sowing/planting, which was suitable for good germination. Di amonium phosphate (DAP) fertilizer was used @ 130 kg/ha during sowing and 70 kg/ha urea was applied during each of the two top dresses given for optimum crop establishment. The average wheat yield was 3.5 t/ha and was compa-

Table 2 Field efficiency of zero till drill in wheat and maize crops establishment

Parameters	Wheat	Maize
Fuel consumption, l/h	1.4	1.25
Speed of operation, km/h	2.2	2.25
Wheel slippage, %	17.0	14.0
Effective field capacity, ha/h	0.18	0.16
Field efficiency, %	83.0	80.0

Table 3 Performance of power tiller operated zero till drill with wheat and maize

Parameters	Wheat	Maize
Seed rate, kg/ha	120	20
Row to row spacing, mm	200	700
Depth of planting, mm	30-40	40-50
Width of opening slit, mm	10-20	12-24
Number of plant/m^2	215	7

rable to conventional method. It was also observed from the intensive field monitoring that the sandy loam soil produced lower yield (2.8 ton/ha) than clay loam soil (4.5 ton/ha) in some areas. The yield of maize in zero till was 1.4 ton/ha less than the conventional tillage method. The sowing/planting cost including land preparation of wheat and maize in zero tillage sowing/planting was 83 % and 89 % less compared to the conventional method. The economics of land utilization of the machine was also determined. It was found from the study that for no loss and no profit, the zero till drill has to be operated for at least 8 ha per year (**Fig. 4**).

Bed Planter

Table 5 shows the performance of the bed planter. The effective field capacity of the planter was comparatively low (0.11 ha/h) for maize planting due to the lower travel speed compared to that of wheat and mungbean sowing since this initial operation had to 'shape' the beds. Thereafter, it was only a 'reshaping.' The field efficiency of the machine was higher (83 %) in wheat and mungbean sowing than in maize planting. This was due to the utilization capability of the bed planter by the operator in mungbean and wheat sowing. Fuel consumption of the machine remained the same, at 1.2 l/h, as normal tilling operation of the power tiller.

Seed rates of wheat, mungbean and maize cultivation were 100, 30 and 20 kg/ha, respectively, which were 14 to 17 % less in wheat and mungbean than the recommended rate of conventional method (**Table 6**). As the depth of seed placement was uniform, there was close contact between seed and soil. Therefore, soil moisture was utilized immediately resulting in good germination. Line to line distance can be adjusted according to the agronomic requirement of the respective crops. The same seed metering device of the planter was used for other crops. The inclined plate metering mechanism was introduced for maize planting in the same system (**Fig. 5**). The growth of mungbean and maize on the bed were not hampered by excess rainfall. During the whole growing period, maize plants did not lodge in bed system. Yield of wheat, maize and mungbean on beds were comparatively higher (24-33 %) than that of conventional system. Bed system facilitated border effect to wheat and mungbean. The

Table 4 Comparison of yield between zero tillage and conventional method (1 US$ = Tk 58)

Planting system	Yield (t/ha)		Planting cost (Tk/ha)	
	Wheat	Maize	Wheat	Maize
Zero tillage system	3.5	8.1	233	262
Conventional method	3.1	9.5	1,250	2,388

Table 5 Performance of power tiller operated bed planter

Parameter	Maize	Wheat	Mungbean
Travel speed, km/h	2	2.22	3
Effective field capacity, ha/h	0.11	0.13	0.19
Field efficiency, %	80	83	93
Fuel consumption, l/h	1.2	1.2	1.2

Table 6 Comparison of yield and yield parameter of bed system and conventional system

Parameter	Wheat		Mungbean		Maize	
	Bed system	Conventional system	Bed system	Conventional system	Bed system	Conventional system
Seed rate, kg/ha	100	120	30	35	20	20
Depth of seed placement, mm	30-40	20-60	20-30	20-30	30-40	30-40
Plant population, #/m^2	231	305	30	50	7	9
Yield, t/ha	4.7	3.8	0.6	0.4-0.5	8.0	6.0
Increase of yield over conventional system, %	24		33		33	

Fig. 3 Relationship between soil moisture and wheel slippage

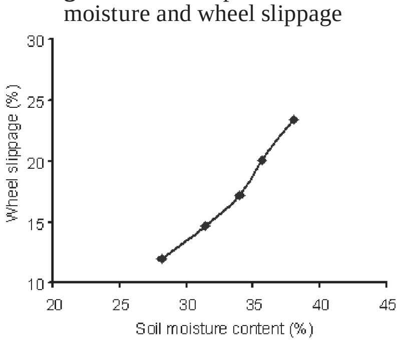


Fig. 4 Annual land use by power tiller operated zero till drill

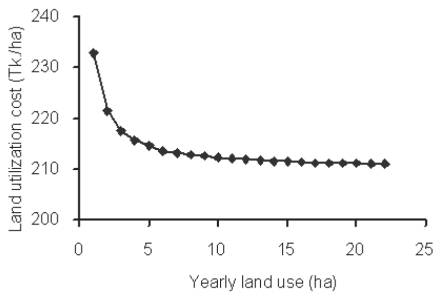


Fig. 5 Photographic view of the seed metering device

planter can be used for reshaping the bed for the next crop and sowing operation can also be done like a tillage system.

Bed formation was easier in sandy loam soil than in clay loam soil. It was also observed that bed height in sandy loam soil was greatly reduced with time compared to clay loam soil. Bed planting system facilitated intercultural operation and water application. The same planter operated in the same furrow controlled 85 % of weeds by slicing action of the furrow wing and also broke the soil crust, which was formed after the first irrigation. The application of irrigation water was much quicker in the bed system than the conventional flood irrigation system. Results showed that 9 hours/ha was required to finish one irrigation in bed planting compared to 15 hours/ha in conventional flood irrigation using the same irrigation outlet. Only one labourer was required to complete the irrigation system compared to three labourers in the conventional system.

Technology Promotion

To create awareness on the benefit of the zero tillage as a resource conservation technology of CIMMYT, the Wheat Research Center with FAO funding has conducted demonstrations, in five different wheat growing locations namely Dinajpur, Jessore, Rajshahi, Noakhali and Jamalpur districts in 2003-04. The technologies have been demonstrated in 180 farmers' fields. The average wheat yield of PT operated zero till drill and conventional methods were 3.5 and 3.1 ton per ha, respectively. It could be mentioned here that farmers could not plant wheat in optimum time due to delay in harvesting preceding rice crop, lack of weed management, sandy loam field selection, and poor fertilizer management. Though the wheat yield was 12 % lower than conventional, the planting cost of zero till method was 83 % less than the conventional system.

The cost of maize planting for forming a new bed was Tk 1,386/ha (1 US $ = Tk 58), which is shown in **Table 7**. The cost of planting was reduced drastically in permanent bed system due to the elimination of land preparation cost, since it only involved the reshaping cost of bed. In the conventional system, the cost of maize planting was much higher than that of bed planting system. In permanent bed planting system, there was no extra cost involved for earthing up during the maize cultivation, whereas it was essential in conventional maize cultivation system. For a maize-mungbean-wheat cropping pattern, the total cost of planting in the bed system was Tk 2,380/ha/y, which was 59 % less than that of conventional system.

During the technology promotion, weed control was the main problem for the zero till wheat expansion. Both researchers and farmers were convinced about zero tillage crop establishments. Availability of planting machinery was another constraint for technology promotion. Machinery cost was beyond the purchase capacity of farmers. They showed interest in using the machinery on a custom hiring system. This system needs to be encouraged and formulated through local manufacturers, advanced growers and policy makers.

Table 7 Bed planting cost over conventional system

Planting system	Planting cost (Tk./ha)			
	New bed	Permanent bed		Total cost (Tk.)
	Maize	Mungbean	Wheat	
Bed system	1,386	497	497	2,380
Conventional system	3,755	988	1,100	5,843

Conclusion

As a part of conservation agriculture in Bangladesh, two power tiller operated farm machines were developed and tested in the field. The Power tiller operated zero till drill is suitable for sowing/planting wheat and maize. However, it is suggested to keep rice residue in the soil and control weeds by applying herbicide before planting. Seed and fertilizer could be placed in right depth in a single operation. Turn-around time between harvesting of monsoon rice and sowing of wheat could be reduced by 10 to 15 days by the drill compared to the conventional tillage system. As a result, yield loss of 1.33 per day of late sowing could be avoided. The sowing/planting cost of wheat and maize was reduced by 83 and 89 %, respectively using the drill. Bed formation and seeding operation can be done in one operation by the power tiller operated bed planter. Bed formation was easier in sandy loam soil compared to clay loam soil. The bed planter was used for sowing/planting wheat, mungbean, and maize and its performance was satisfactory. In bed planting system, only nine hours were required to irrigate one hectare land compared to 15 hours in conventional flood irrigation. After the formation of initial bed, the subsequent crops can be cultivated on it by reshaping the bed without tillage operation by the same bed planter.

REFERENCES

Anonymous. 1991. Calculation method of farm machinery utilization. Farm mechanization planning (Mechanization Management), Vol. 3. JICA, TIATC, Japan.

BBS (Bangladesh Bureau of Statistics). 2002. Statistical Yearbook of

Bangladesh. Statistics Division, Ministry of Planning, Govt. of the Peoples' Republic of Bangladesh, Dhaka.

ECAF (European Conservation Agriculture Federation). Undated. Conservation agriculture: environmental benefits. http:/www. ecaf. org/English/Envirom.htm.

ECAF (European Conservation Agriculture Federation). 2002. Hold back the desert with conservation agriculture. http:/www. ecaf. org/ English/pagenews.htm.

Fahong, W.,W. Xuquing, and K. D. Sayre. 2003. Comparison study on two different planting methods for winter wheat in China. Bed planting course, CIMMYT, Mexico.

Gupta, R. K., P. R. Hobbs, J. K. Ladha, and S. V. R. K. Probhakar. 2002. Resource conserving technologies: Transforming the rice-wheat systems of the Indo-Gangetic Plains. Rice-wheat consortium–a success story. Asia Pacific Association of Agricultural Research Institutes. Bangkok.

Gupta, R. K., S. Singh, R. K. Malik, G. Singh, R. S. Mehla, G. Sah, J. Tripathi, R. K. Sharma, P. R. Hobbs, J. K. Ladha, and B. K. Singh. 2003. Zero tillage in Rice-Wheat Systems: Frequently asked questions. Technical Bulletin No.6, Rice-Wheat Consortium for the Indo-Gengetatic Plains, New Delhi.

Hobbs, P. R., G. S. Giri, and P. Grace. 1997. Reduced and zero tillage options for the establishment of wheat after rice in South Asia. RCW Paper No. 2. Mexico, D.F.: Rice-wheat consortium for the Indo-Gangetic Plains and CIMMYT.

Hobbs, P. R. and R. S. Mehla. 2003. The problem of late planting wheat. Addressing resource conservation issues in Rice-Wheat Systems of South Asia. A resource book. Rice Wheat Consortium for Indo-Gangetic Plains, International Maize and Wheat Improvement Centre. New Delhi.

Meisner, C. A., E. Cevedo Flores, K. D. Sayre, I. Ortiz-Monasterio, and D. Byerlee. 1992. Wheat production and grower practices in the Yaqui Valley, Sonara, Mexico. Wheat special report No. 6, CIMMYT, Mexico.

Meisner, C. A., M. Bodruzzaman, M. R. Amin, E. Baksh, A. B. S. Hossain, M. Ahmed, and M. A. Sadat. 2001. Conservation tillage options for the poor, small landholders in South Asia. Conservation Agriculture, A worldwide challenge: Environment, farmers experience, innovations, socio-economy, policy. I World Congress on Conservation Agriculture, Volume II: pp: 683-688, Madrid.

Meisner, C. A. 1992. Report of an on-farm survey of the Mymensingh region and Tangail: Wheat growers’ practices, perceptions, and their implications, Monograph No. 9, Bangladesh Agricultural Research Institute. Wheat Research Center, Nashipur, Dinajpur, September 1992.

Meisner, C. A. 1996. Report of an on-farm survey of the Greater Comilla Region: Wheat growers’ practices, perceptions, and their implications, Monograph No. 13, Bangladesh Agricultural Research Institute. Wheat Research Center, Nashipur, Dinajpur, June 1996.

Meisner, C. A. 1999. Report of an on-farm survey of the Greater Faridpur Region: Wheat growers' practices, perceptions, and their implications, Monograph No. 14, Bangladesh Agricultural Research Institute. Wheat Research Center, Nashipur, Dinajpur, June 1999.

Meisner, C. A. 2001. Report of an on-farm survey of the Greater Sylhet Region: Wheat growers' practices, perceptions, and their implications, Monograph No. 16, Bangladesh Agricultural Research Institute. Wheat Research Center, Nashipur, Dinajpur, July 2001.

Saunders, D. A. 1988. Crop management research: Summary of results, 1983-88. Monograph No. 5: Wheat Research Centre, Nashipur, Dinajpur.

Saunders, D. A. 1990. Report of an on-farm survey of the Dinajpur District: Farmers' practices, and problems, and their implications, Monograph No. 6, Bangladesh Agricultural Research Institute. Wheat Research Center, Nashipur, Dinajpur, June 1990.

Saunders, D. A. 1991. Report of an on-farm survey of the Jessore and Kushtia Districts: Wheat farmers' practices, and their implications, Monograph No. 8, Bangladesh Agricultural Research Institute. Wheat Research Center, Nashipur, Dinajpur, June 1991.

Sayre, K. D. 2003. Raised bed system of cultivation. Bed planting course. CIMMYT, Apdo. # 370, P.O. Box 60326, Houston.

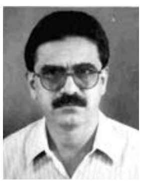
Washington Free Press. 2001. Conservation agriculture: “Next green revolution”. http:/www. Washingtonfreepress.org/54/Next Green Revolution.ht

■■

Development and Performance Evaluation of a Tractor Operated Cotton Stalk Shredder Cum Insitu Applicator

by
T. Senthilkumar
Assistant Professor
Krishi Vigyan Kendra
Vamban Colony - 622 303
Pudukkottai Tamilnadu
INDIA

R. Manian
Professor
Dept. of Farm Machinery
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641 003
INDIA



K. Kathirvel
Professor
Dept. of Farm Machinery,
Agricultural Engineering College
and Research Institute,
Tamil Nadu Agricultural University,
Coimbatore - 641 003
INDIA

Abstract

Incorporation of cotton stalks into the soil ensures rapid decomposition. The most rapid decomposition occurs when residue is placed 10 cm deep and when stalks are shredded as finely as possible also. The present migration of labour from rural sector to scholastic jobs in urban areas necessitates the need for mechanizing the farming operation of cotton stalk shredding and incorporation in the field. A tractor operated cotton stalk shredder consisting of a shredder assembly, power transmission system with hydraulic motor, hitch frame and hydraulic lift was developed. The shredding unit consisted of main shaft and two swing back type rotary blades. Lifting and lowering of the shredding unit was carried out by the hydraulic lift mounted in the front of the tractor. The power for the shredder was transmitted form the hydraulic motor and reduction gear box. The commercially available rotavator was used as *insitu* applicator for incorporation of shredded cotton stalks Shredding cotton stalks was accomplished by the shredder in front portion of the tractor and incorporation of the shredded cotton stalks into the soil was done by rotary tiller in the rear portion of the tractor. The unit was evaluated for performance. Experiments were conducted with 4 treatments; viz. disc ploughing with the standing cotton stalks, operation of the cotton stalk shredder cum *insitu* applicator at 2.0, 2.5 and 3.0 km h^{-1} to find out the efficient method of cotton stalk shredding and *insitu* application.

Introduction

Cotton has been one of the main sources of India's economic growth and a foreign exchange earner. Cotton is grown commercially over 111 countries through out the world. In India, the major area of cotton is cultivated under rainfed conditions. The area under cotton cultivation in India is about 7.8 million ha with a production potential of 17.0 million bales. Cotton stalk is used as an agricultural waste in large quantities in the cotton growing areas. In India nearly 15 million tonnes of cotton stalks are produced every year (Anonymous, 1999).

There are a lot of stalks left on the field after cotton harvesting. Normally, the plants are removed by either manual pulling or cutting with a sickle up to a height of 50 to 75 mm above the ground surface and burnt later. The above facts necessitate the urgent need for a stalk shredder cum *insitu* applicator.

Review of literature

Sumner et al. (1984) developed a test unit with a pair of counter rotating wheels and pneumatic tires and to determine the effect of operating variables and design elements on the efficiency of cotton plant removal from the soil.

Bansal et al. (1987) designed a stubble collector cum planker. It consisted of a wooden plank fitted with mild steel spikes to an angle iron frame and has a fitting mechanism. Yumak et al. (1990) developed a two-row machine to pull cotton stalks after harvesting cotton. The machine covered an area of 9.2 ha h^{-1} and was 95 % efficient. The broken stalks and plants not pulled were 2 % and 6 %, respectively.

Gangade et al. (2000) conducted a comparative study on different methods of cotton stalk removing and they concluded that the plant removing/uprooting efficiency for the tractor operated uprooter, tractor operated slasher and tractor drawn V blade were 80 %, 100 % and 99 %, respectively. Sheikh EI Din Abdel Gadir EI Awad (2000) developed a two unit digger for cotton stalk uprooting. The unit of digger consisted of a horizontal cutting edge of 0.4 m length.

Materials and Methods

Development of a Tractor Operated Cotton Stalk Shredder

The shredding of cotton stalks by shredder and incorporation of the shredded cotton stalks into the soil has to be accomplished in a single pass of the tractor. For simultaneous shredding and incorporation of the cotton stalks, it was proposed to mount the shredder in the front portion of the tractor.

A prototype tractor operated cotton stalk shredder with optimized levels of variables of (2 blades, 0 deg rake angle and 12 mm blade thickness) was developed (**Fig. 1**). The functional components of the unit were:

1. Shredder assembly
2. Power transmission system with hydraulic motor
3. Hitch frame
4. Hydraulic lift

Shredder Assembly

The main frame or casing of the cotton stalk shredding unit (110 x 110 mm) was made of 6 mm mild steel plate. The shredding unit consisted of main shaft and the shredding blades. Two number of swing back type rotary blades were hinged to the main drive shaft which were connected with the transmission gear box. The side plates of the main frame or casing attached with the float, 1440 x 220 mm, was made of 3 mm mild steel sheet and 62.5 x 10 mm mild steel flat. Provisions were made to adjust the height of the float according the height of shredding required.

Transmission System

There are three basic methods of transmitting power; electrical, mechanical and fluid power. Most applications actually use a combination of the three methods to obtain the most efficient overall system. Fluid systems can transmit power more economically over greater distances than can mechanical types. Hence, the hydraulic drive was selected as the driving source for shredder. A 1:1.75 speed ratio bevel gear box is mounted On the top of the shredder assembly. A hydraulic motor is fixed for providing drive to the shredder assembly. The drive was obtained from the main output shaft of the hydrometer to the gearbox to get the required rpm of 1200. The drive was transmitted from the gearbox to the main vertical shaft of the shredding unit.

Hitching Frame

Both the sides of the shredding unit was hinged with box like arms made of two 75 × 37.5 × 6.25 mm mild steel channel. The other end of the arms was connected with the chassis of the tractor frame.

Hydraulic Lift

Lifting and lowering of the shredding unit was carried out by the hydraulic cylinder mounted in the front of the tractor.

Incorporation of Shredded Stalks Into the Soil

The organic matter is transformed through the process of decomposition and humification into humus which helps improve the physical, chemical and biological properties of soil. The incorporation of crop residues in soil plays an important role in maintaining soil productivity.

Fig. 1 Tractor operated cotton stalk shredder cum *insitu* applicator

Fig. 2 Operational view of tractor operated cotton stalk shredder cum *insitu* applicator

Insitu Applicator

The rotary cultivator or rotavator is widely considered to be the most important tool as it provides fine degree of pulverization enabling the necessary rapid and intimate mixing of soil. The benefits of the rotavator are (1) effective pulverization of soil for good plant growth; (2) stubble and roots are completely cut and mixed with the soil; and (3) proper ground leveling after the operation. Hence, the tractor operated commercially available rotavator is selected as *insitu* applicator for incorporation of shredded cotton stalks.

Field Performance Evaluation of the Prototype Unit

The developed prototype cotton stalk shredder was mounted on a 59 hp tractor (**Fig. 2**) and evaluated for performance in shredding cotton stalks in the field. The prototype equipment was evaluated at an optimized blade speed with three forward speeds of 2.0, 2.5 and 3.0 km h^{-1}. The prototype was evaluated for performance in terms of shredding efficiency.

Results and Discussion

Field Performance Evaluation of the Prototype Unit

The proto type cotton stalk shredder cum *insitu* applicator was evaluated with optimized parameters in the field at three levels of forward speed; viz. 2.0, 2.5 and 3.0 km h^{-1}.

The shredding efficiency and mean value of cotton stalk length are shown in **Table 1**. Increase in speed from 2.0 to 3.0 km h^{-1} resulted in decreased shredding efficiency from 91.63 to 82.18 % and increased the mean length of shredded cotton stalk by 89.8 %. The operating speed of 2.0 km h^{-1} yielded lowest mean length of cut of shredded cotton stalk of 108 mm and highest shredding efficiency of 91.63 %. Hence forward speed of 2.0 km h^{-1} may be selected as the optimized speed for the cotton stalk shredder cum *insitu* applicator.

The operational view of cotton stalk shredder cum *insitu* applicator is shown in **Fig. 2**.

Conclusions

A front mounted tractor operated prototype cotton stalk shredder (2 blades, 0 deg rake angle and 12 mm blade thickness) has been developed and evaluated for its performance with three forward speeds of 2.0, 2.5 and 3.0 km h^{-1} and optimized for maximum shredding efficiency. A tractor operated (rear mounted) commercially available rotavator was selected as *insitu* applicator for incorporation of shredded cotton stalks. Increase in operating speed from 2.0 to 3.0 km h^{-1} resulted in decreased shredding efficiency from 91.63 to 82.18 %. Increase in operating speed from 2.0 to 3.0 km h^{-1} resulted in increased mean length of shredded cotton stalk from 108 to 205 mm. The actual field capacity of the prototype tractor operated cotton stalk shredder cum *insitu* applicator was 0.24 ha h^{-1}.

Experiments were conducted with 4 treatments viz. disc ploughing with the standing cotton stalks and operation with prototype cotton stalk shredder cum *insitu* applicator with 2.0, 2.5 and 3.0 km h^{-1} forward speed to find the efficient method of cotton stalk shredding and *insitu* application.

Table 1 Shredding efficiency and mean value of shredded cotton stalk length at 3 levels of forward speed

Speed km h^{-1}	Shredding efficiency, %	Mean length of shredded cotton stalk, mm
2	91.63	108
2.5	85.29	188
3	82.18	205

REFERENCES

Anonymous. 1999b. Cotton Review of the world situation. International Cotton Advisory Committee. September-October, 15(1): 20-21.

Bansal, N. K., D .N. Sharma, and M. L. Jain, 1987. Development and field evaluation of a stubble collector-cum-planker. Agricultural Mechanization in Asia, Africa and Latin America, 8(1): 57-59.

Gangade, C. N., P. G. Patil, and S. S. Dhanphule. 2000. Comparative study of different methods of cotton stalk removing. PKV Res. J., Vol.24(2): 87-89.

Sheikh EI Din Abdel Gadir EI Awad. 2000. Development and performance of 2-unit digger for cotton stalks uprooting and groundnut lifting. Agricultural Mechanization in Asia, Africa and Latin America, 31(4): 46, 52-56.

Sumner, H. R., G. E. Monroe, and R. E. Hellwig. 1984. Design elements of a cotton plant puller. Transaction of the ASAE, 27: 366-369.

Yumak, I. and U. Evcim. 1990. A two-row cotton stalk pulling machine. International congress on Mechanization and energy in Agriculture, Proceedings of a conference held in Adana, Turkey: 416-425.

■■

Design Development and Performance Evaluation of Cotton Loading and Unloading Machine for Heaping

by

S. K. Shukla
Scientist (Mech. Engg.)
Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT) ICAR,
Nagpur - 440 023
INDIA

V. G. Arude
Scientist of Agricultural Engineering
Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT) ICAR,
Nagpur - 440 023
INDIA

P. G. Patil
Scientist (Sr. Scale),
Agricultural Engineering and Officer In-charge
Ginning Training Centre of Central Institute for Research on Cotton Technology (CIRCOT) ICAR,
Nagpur - 440 023
INDIA

Abstract

Heaping of cotton is a very tiresome and time-consuming operation at a gin, since a person has to walk 100 to 125 m and climb up to a height of 8.5 to 9.0 m to heap the cotton. This also adds some trash to the cotton. To overcome these difficulties in gins, a cotton loading/unloading machine for heaping operation was designed, developed and performance evaluated. The major components of the machine are inlet flexible pipe, casing, impeller, perforated conical disc, electric motor, outlet GI pipe and trolley. Three diameters of perforations were tried to get the maximum output and efficiency. Three mm perforations were the optimum size to prevent choking for the attachment at the inlet side of impeller. The capacity of the machine was 2,400 kg cotton/h. The fine trash content removal efficiency was an average of 20.8 percent. There was no measurable fibre damage observed during the conveying of cotton through the developed machine.

Introduction

India ranks first in the world in area under cotton cultivation with 8.6 mha during 2001 to 02 and largest producer of cotton fibre in the world after China and USA. Cotton is transported to nearby gin after picking from the field by means of either bullock carts, tractors or trucks where it is ginned and baled. Cotton is very voluminous commodity having density of 120 kg/m^3, hence, it is stored in the form of heaps in gins. For heaping of cotton in gins, it is first unloaded manually on the open ground from the transported vehicle then carried by human beings on their heads in bamboo baskets to the heaping side. Cotton is placed in layers and compacted by human beings with their legs so that the desired stability of heaps is achieved. A final heap looks like a trapezoid with a base of approximately 10 × 12 m, a top of 6 × 10 m and height of about 8.5 to 9.0 m (**Fig. 1**). The weight of a heap is 150 to 200 tones. Approximately 600 to 700 man-hours are required to make a heap and 8 to10 such heaps are generally required for a ginnery at one time to store the cotton. This is very tiresome and time-consuming operation as a person has to walk 100 to 125 m and climb up to a height of 8.5 to 9.0 m, in order to heap the cotton. In addition to this, some trash is added in the cotton due to human intervention during manual heaping operation.

To overcome these difficulties in manual heaping, a mechanical cotton loading/unloading device for heaping operation in a gin was developed on the principal of the Rembert fan. Various fibre properties of cotton were determined in order to design and optimize the dimensions of the various components of the cotton loading/unloading device. The prototype was tested and evaluated for its capacity and cotton fibre properties.

Traditional Cotton Loading/Unloading Method

There are two traditional methods of cotton loading/unloading presently used in the gins of developed countries. In the first method, a belt conveying system, as shown in **Fig. 1**, is used to load/unload the cotton (Campell, 1955). In this system a flat belt of 600 mm width is used to convey the cotton. The height of transportation can be varied from 4.5-9.0 m with the help of a rope pulley mechanism. The entire assembly can also be moved to and fro with the help of a trolley over which the entire assembly is mounted. The initial cost of belt conveying systems are very high but the operational charges is less.

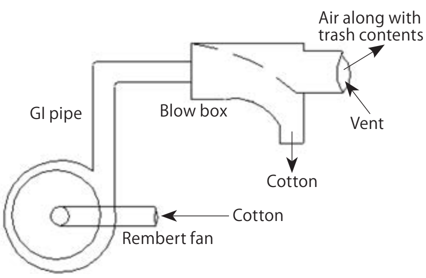
In the second method, a fan and an air separator are used to load/unload cotton in gins. This method is popularly known as pneumatic loading/unloading system. Fans are used to produce the flow of air at a sufficient velocity to propel cotton through conveying pipes. Centrifugal and axial flow fans are commonly used in cotton gins, but the majority is centrifugal fans (Baker et al., 1994). The pneumatic conveying systems require less initial cost but higher running cost. The running cost of the pneumatic conveying system is higher as it needs an air separator to separate the cotton from the air stream (Wright, 1977). Separators constitute a main source of power waste, especially when badly worn or have leaky connections. Even new and well-sealed separators have a significant intake of air through the vacuum wheel.

The separator loss was found to be more than 35 percent (Campell, 1955). However, separators can be eliminated entirely by installing a Rembert-type fan, discharging the cotton into a blow box or 300 angle screen box (Stedronsky et al., 1941) as shown in **Fig. 2**.

The main difference between a simple centrifugal fan and Rembert fan is that the latter uses a perforated flat or conical disc at its inlet side. This perforated flat or conical disc is used to avoid the entering of cotton inside the impeller blades, which damages the cottonseed and fibres and causes the choking of the system.

All the air handled by the Rembert fan is employed in loading/unloading the cotton. This system is very efficient as it does not employ air separator and vacuum dropper which are the sources of major energy losses in cotton conveying system, to separate cotton from air.

Fig. 2 Diagram showing Rembert fan and screen blow box



Materials and Methods

The developed cotton loader/unloader machine for heaping consists of inlet flexible pipe, casing, impeller, perforated disc, electric motor, outlet GI pipe and trolley (**Fig. 3**). A fifteen hp electric motor is used to drive the machine. The height of discharge is 9 m and the length of inlet pipe can be varied as per the requirement. The diameters of inlet and outlet pipes are 300 mm each. The function of each part and their brief description are as follows:

Inlet Flexible Pipe

This is basically circular flexible pipe used to suck the cotton from a particular distance. It can suck the cotton even from the cotton-carrying vehicle itself. The length of this pipe was kept as 3 m for testing.

Casing

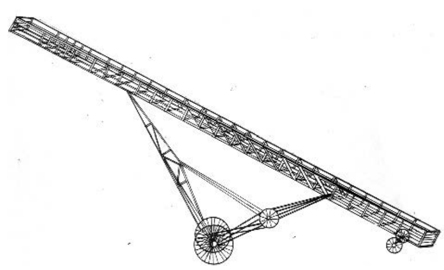
The fan casing is so designed as to minimize the loss of kinetic head through eddy formation of the air. The efficiency of the fan largely depends on the type of casing. In the present design a volute type of casing is used, which is of a spiral form and the cross section area of the moving air stream gradually increases from the tongue towards the delivery pipe as shown in **Fig. 4**. The cross section area at any point is proportional to the quantity of air flowing across the section and therefore the mean velocity remains constant (Lal, 1975). Thus, the losses of kinetic head, which would occur if simply a circular casing were employed, are avoided.

Impeller

It is a wheel or rotor provided with a series of backward curved blades or vanes and mounted on a

Fig. 1a Heap making with the help of workers

Fig. 1b Belt conveyor type cotton loader/unloader machine for heaping



shaft coupled to an electric motor. The pressure head developed by centrifugal action is entirely due to velocity imparted to the air by the rotating impeller. The backward curved vanes were selected as it provides high efficiency.

Perforated Disc

When the cotton was allowed to pass through the normal impeller the cotton was thrashed very badly between the blades of centrifugal impeller. This resulted in the crushing of cottonseed and breakage of cotton fibres. In order to avoid this problem a C.R. perforated alloy disc (2 mm thick and 320 mm diameter) was designed and developed to attach at the front of the impeller as shown in **Fig. 5**. **Fig. 6** represents the impeller with attached perforated disc. The diameter of perforations of the attached disc was 3 mm.

Trolley

The developed prototype was mounted over a moveable trolley. The trolley consisted of four specially designed MS wheels. These wheels were fitted along with ball bearings over shafts. A lockable mechanism was incorporated in the trolley so that trolley could be locked at any position. Hence, there is no chance of trolley movement at the time of operation. A pivot bearing was also fitted at the center of the trolley so that it could be easily moved at any locations.

Additional design details for this machine are given in **Table 1**.

Performance Evaluation

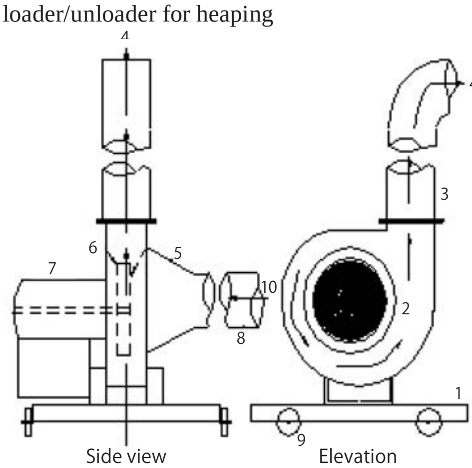
Three different perforated discs with perforation diameters of 1.75 mm, 3.0 mm and 8.0 mm were attached at the front side of impeller to assess the performance of the developed cotton loader/unloader machine for heaping. These perforation diameters were selected based on the ready availability of discs in the market. For each type of perforated disc, three different sets of trials were conducted to optimize the perforation diameter of discs, output and the efficiency of the developed cotton loader/unloader machine for heaping. For these trials, this machine was installed in our laboratory. 500 kg of cotton was used in each trial from a single lot. The cotton was fed manually and uniformly to the machine in each trial. The conveyed cotton obtained from each trials and control cotton, were ginned on double roller (DR) gins. The lint samples obtained after ginning were analyzed on MAG-SITRA trash separator for fine trash content and on High Volume Instrument (HVI) for its fibre properties; viz. 2.5 % span length, uniformity ratio, fineness and strength.

Results and Discussion

The time required to clean the cotton, capacity of the machine, fibre properties and trash contents are shown in **Tables 2-4** for discs of perforation diameters 1.75 mm, 3.0 mm and 8.0 mm, respectively. The average output capacity and efficiency of fine trash content removal percentage for each perforated discs are shown in **Table 5**.

It was found that the prototype was working satisfactorily for discs of perforation diameters 3 mm and 1.75 mm. But the disc with perfora-

Fig. 3 Cotton loader/unloader for heaping



1. Trolley, 2. Perforated disc, 3. GI pipe, 4. Outlet, 5. Reducer, 6. Impeller, 7. Electric motor, 8. Flexible inlet pipe, 9. Wheels, 10. Inlet

Fig. 4 Diagram showing volute casing and impeller

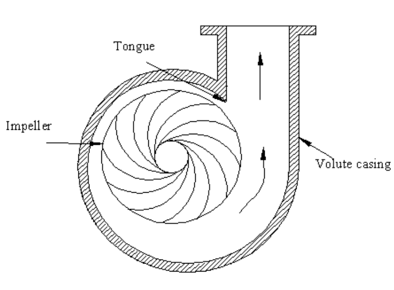


Fig. 5 Perforated disc of 8 mm perforations

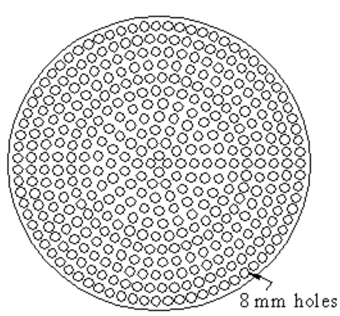
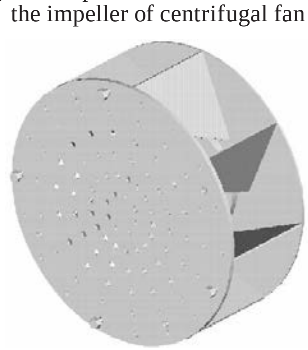


Fig. 6 Flat perforated disc attached on the impeller of centrifugal fan



tion diameter of 8 mm was not giving satisfactory result in spite of its maximum output. The perforations of this disc were getting choked due to the accumulation of cotton fibres inside the perforations, which may clog the casing in the long run. It was due to the reason that the cotton was entering the casing of the fan at a very high velocity, which was impacting the attached perforated disc at very high force. Due to this high impact force, some fibres from the cotton were detached from their seeds, which were accumulating inside the perforations of the disc. The discs with a perforation diameter 3 mm was giving more output. Hence, it was concluded that disc of perforations diameter 3 mm was the optimum disc even though it was giving slightly lower efficiency of fine trash removal since fine trash removal was the secondary requirement for the cotton loader/unloader machine for heaping.

The capacity and average efficiency of fine trash content removal of the developed machine were found to be 2,400 kg cotton/h, 20.8 %, respectively, for the disc with 3 mm diameter perforations. The 2.5 % span length of lint fibres varies from

Table 1 Design characteristics of cotton loader/unloader for heaping

Items		Specifications
Fan	Air flow rate, m^3/h	5,700
	Water gauge pressure, mm	600
	Height, mm	3,000
Trolley	Length, mm	1,400
	Width, mm	1,200
	Number of wheels	4
	Distance between centre of wheels, mm	900
	Diameter of wheels, mm	160
	Diameter of wheel shaft, mm	8
Impeller	Diameter, mm	550
	Width, mm	75
	Speed, rpm	2,920

Table 2 Capacity, cleaning performance and fibre quality data of the machine for disc of perforations diameter 1.75 mm

Experiment	Time required to process, s	Capacity, kg/h	Fine trash content, %	2.5% Span length, mm	Uniformity ratio, %	Fineness (Micronaire)	Bundle strength, g/tex
Control	-		4.8	24.6	45	4.1	22.2
Trial 1	801	2,247.2	3.4	24.4	46	4.0	21.9
Trial 2	795	2,264.2	3.9	24.5	47	4.1	22.0
Trial 3	800	2,250.0	4.1	24.3	46	4.1	21.8
Average	798.7	2,253.7	3.8	24.4	46.3	4.0	21.9

Table 3 Capacity, cleaning performance and fibre quality data of the machine for disc of perforations diameter 3.0 mm

Experiment	Time required to process, s	Capacity, kg/h	Fine trash content, %	2.5% Span length, mm	Uniformity ratio, %	Fineness (Micronaire)	Bundle strength, g/tex
Control	-		4.8	24.6	45	4.1	22.2
Trial 1	755	2,384.1	4.1	24.4	45	4.1	21.6
Trial 2	748	2,406.7	3.6	23.9	47	3.9	22.0
Trial 3	753	2,390.4	3.9	24.1	46	4.1	22.1
Average	752	2,393.6	3.9	24.1	46	4.0	21.9

Table 4 Capacity, cleaning performance and fibre quality data of the machine for disc of perforations diameter 8.0 mm

Experiment	Time required to process, s	Capacity, kg/h	Fine trash content, %	2.5% Span length, mm	Uniformity ratio, %	Fineness (Micronaire)	Bundle strength, g/tex
Control	-		4.8	24.6	45	4.1	22.2
Trial 1	722	2493.1	3.6	23.8	46	4.1	22.3
Trial 2	718	2507.0	3.5	24.7	47	4.3	22.1
Trial 3	725	2482.8	3.9	24.2	46	4.2	21.9
Average	721.7	2494.1	3.6	24.2	46.3	4.2	22.1

Table 5 Performance of the machine

Diameter of perforations, mm	Average capacity, kg/h	Average fine trash content removal efficiency, %	Remarks
1.75	≈2,250	25	Choking of holes was observed
3	≈2,400	20.8	Choking of holes was not observed
8	≈2,500	18.8	Choking of holes was not observed

23.8 to 24.6 mm for different trials as well as for control and no fibre damage occured while conveying through the developed cotton loader /unloader machine with all three types of selected perforated discs.

Conclusions and Recommendations

- The overall performance of the developed machine was satisfactory.
- The capacity of the developed cotton loader/unloader machine for heaping was found to be 2,400 kg cotton/h.
- Efficiency of fine trash content removal was found to be 20.8 percent.
- There was no measurable fibre damage observed while conveying through the developed machine in all trials of cleaning operations.
- The disc with perforations diameter of 3 mm was optimum without any choking for the attachment at the inlet side of impeller.
- There was no vibration found even after attaching a 9 m tall outlet pipe.
- The space available inside the casing should match the capacity requirement otherwise choking is likely to occur.

REFERENCES

Baker, R. V., E. P. Columbus, R. C. Eckley, and B. J. Stanley. 1994. Pneumatic and mechanical handling systems. Cotton Ginners Handbook. USDA Agricultural Handbook 503: 143-171.

Campell, R. D. 1955. Cotton Ginners Handbook. Arkansas-Missouri cotton ginners association. Inc. Arkansas, USA: 18pp.

Lal, J. 1975. Hydraulic Machines. Meteopolitan Book Company, New Delhi:352 pp.

Narayanan, S. S and V. Sundaram. 1999. Improved sustainability of cotton in India by enhancing its production and improving quality. Paper presented in International seminar on cotton and its utilization in the 21st century held at CIRCOT, Mumbai during December 10-12th 1999. Book of papers: 4-15.

Sandhar, N. S. 1999. Present practices and future needs of mechanization of cotton picking/harvesting in India. Paper presented during Indo-Uzbek Workshop on Agricultural Research during November 15-16th 1999 held at CIAE, Bhopal. Book of papers: 50-55.

Stedronsky, V. L., T. L. Baggette, and A. J. Johnson. 1941. Reducing power waste in operating cotton gins. USDA circular No. 601: 10 pp.

■■

(Continued from page73)

Ergonomically Designed Thresher

platform and chute can reduce the possibility of injury among thresher operators.

REFERENCES

Kumar. A., M. Varghese, and D. Mohan. 2000. Equipment related injuries in agriculture: an international perspective. J. Injury Prev. Control 7 (3), 175-186.

BIS 11619, 1986. Power thresher, spike tooth type. Bureau of Indian Standards, New Delhi.

Mohan, D. and R. Patel. 1992. Design of safer agricultural equipment: application of ergonomics and epidemiology. Int. J. Ind. Ergonomics. 10, 301-309.

Patel, R., A. Kumar, and D. Mohan. 2000. Development of ergonomic evaluation facility for Indian tractors. Applied Ergonomics. 31, 311-316.

■■

Ergonomically Designed Thresher

by

S. V. Gole
Professor and Head, Management Dept.
Shri Ramdeobaba Kamla Nehru
Engineering College
Nagpur - 440 013
INDIA
Emali: rashmishahu@yahoo.co.uk

Rashmi Shahu
Lecturer, Management Dept.
Shri Ramdeobaba Kamla Nehru
Engineering College
Nagpur - 440 013
INDIA

Abstract

More and more people are suffering from repetitive strain injuries as our society becomes increasingly mechanized. As humans, of course, we are little different from other living things. Being human means we can override our instincts, override pain and discomfort, and override hunger and thirst and fear; all in the service of a consciously chosen goal. This is a tremendous benefit. Civilization would not exist without this ability. Threshers are used extensively on Indian farms for threshing grains, but are involved in a significant proportion of limb crush injuries. International safety standards are somewhat difficult to enforce because manufacture of machines is done at widely dispersed local workshops. Locally made machines are used for crop production and post-harvesting operations, with a great deal of manual work.

Introduction

The mechanization of agricultural practices has resulted in increased agricultural productivity in India but at the same time, the incidence of traumatic injuries among agricultural workers seems to have increased also. It is estimated that every year in Haryana, Punjab and Uttar Pradesh (three states of northern India) alone there may be 5,000-10,000 deaths, 15,000-20,000 amputations and 150,000-200,000 serious injuries due to agricultural related activities (Mohan and Patel, 1992). Among these, threshing machines are responsible for a significant number of serious injuries (Mohan and Patel, 1992). Threshers are power driven machines designed for threshing wheat and rice during the harvesting season. These machines use auxiliary power from tractor power take off or electric motors/diesel engines.

The typical thresher is fitted with a feeding chute at a slope of 10-151 at the mouth of the threshing drum. Thresher injuries have not been reported by any high-income countries (HICs) after 1969 (Kumar, 2000). However, the number of powered threshers has increased from 0.2 million in 1971-72 to 3 million in 1995-96 on Indian farms (Singh, 1997). Mohan and Patel (1992) recorded that this machine caused 2 % of total agricultural injuries though they are used only for a few days in the whole year. A study from Pakistan says that threshers were associated with 16 % of injuries (Muftietal, 1989). They reported that belt entanglement, electric shock and feeding the crop without safety were main reasons attributed to thresher injuries; the mechanical failures were responsible for injuries were 17 %. Singh and Sinha (1980) reported 30 thresher injuries out of 50 in a survey from India, but the study did not give any details of type of injury or mechanism of injury. In another study from Punjab, India, the human factors were associated with thresher injuries in 73 % of the cases. These included inattentiveness, wearing of loose garments, overwork and physical incapability (Rawal, 1988). However, these observations were not based on any detailed investigations. No study has evaluated improvements in design or any safety mechanisms.

Fig. 1 Cutting with sickle

Fig. 2 Hand threshing

Fig. 3 Mechanical threshing

Traditional Thresher

Harvesting Systems Overview

Harvesting consists of four basic operations:

- Cutting: cutting the mature panicles and straw above-ground (**Fig. 1**).
- Handling: moving the cut crop to the threshing location (**Fig. 2**).
- Threshing: separating the paddy grain from the rest of the cut crop (**Figs. 3**, **4**, **5**).
- Cleaning: removing immature, unfilled and non-grain materials.

Existing Method

A random survey of 100 threshers was carried out to obtain control data for dimensional and operator work details in the study area. These data were compared with the dimensions of threshers involved in injuries to identify the factors associated with injuries. Based on the information regarding factors associated with injuries, a safer design of thresher was prepared using anthropometric data of the Indian population (Patel, 2000). Indian stature was used to generate other body part dimensions (Roebuck et al., 1975) for safer thresher design.

Observations

Table 1 gives the details of the victims and the body parts injured. The right hand was involved in 80 % cases, the left hand was involved in 15 % and other body parts 5 %. The analysis of machine parts associated with injuries revealed that the threshing drum and the feeding system were involved in 19 cases, belt and pulley in 6 cases and rest by any other machine part. Injury victims were feeding the chute from the left in 15 cases, from the right in 9, and from the front in 2 cases.

The factors reported included unstable platform, improper work posture, small chute dimensions, feeding of small crop pieces, jerks due to high moisture content in the crop bundles and entanglement of body parts into the auxiliary power transmission system. The table below gives the thresher chute dimensions and anthropometric dimensions of male worker for safer thresher design.

Chute-opening height was smaller (mean 15 cm) in injury-associated threshers as compared to Control threshers (mean 18 cm). Because of the smaller chute-opening height, the operator had to use greater force to push the crop in with his hands, which could take the hands close to the fast moving threshing drum (600-700 rpm) which results in an injury. Mean chute cover length of threshers was 27 cm compared to 36 cm for the control group of threshers. This trend had a direct relationship with anthropometric dimensions of forearm, in that higher chute cover length prevented the forearm from coming into contact with the threshing drum. The mean chute length of injury-associated threshers was 69 cm whereas control thresher chute length was 80 cm.

The analysis of thresher chute parameters shows that chute cover length and chute-opening height are critical dimensions which influence the outcome of whether an operator sustains injuries or not. Chute-opening height should be such that it ensures smooth feeding without excessive force application. Some operators stand on unstable/high platforms causing a bending work posture. As a result their torsos are high with respect to the chute. While feeding the crops into the chute they bend over it and, in the event of a jerk or loss of balance, the torso weight helps push the hands

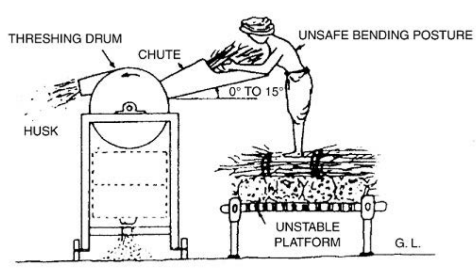
Table 1 Age, gender and body part injured

Case No.	Age, years	Gender	Body Parts
1	20	male	Right hand elbow
2	35	male	Left hand fingers
3	35	male	Right hand index finger
4	15	male	Right hand fore arm
5	21	male	Right hand
6	24	male	Right hand
7	14	male	Right hand
8	22	female	Right hand fore arm
9	50	male	Right hand
10	17	male	Right hand
11	29	male	Right hand fore arm
12	30	female	Death case
13	30	male	Left hand fingers
14	13	male	Right hand fingers
15	21	male	Right hand
16	40	male	Left han
17	22	male	Right hand fore arm
18	30	male	Right hand
19	60	male	Right hand fingers
20	25	male	Right hand
21	16	male	Right hand fore arm
22	22	male	Right hand fore arm
23	16	male	Right hand
24	17	male	Right hand
25	21	male	Left/right hand

Fig. 4 Pedal thresher

Fig. 5 Feed-in thresher

Fig. 6 Existing method



into the drum, resulting in injury.

The above analysis shows that the injury-associated threshers as compared to the control sample had shorter chutes, shorter chute covers and narrow chute openings. According to the Bureau of Indian standard BIS: 11691-1986, threshers should have chute covers with lengths of 45 cm and chute lengths of 90 cm, considering the average forearm length of Indian men. But, as **Fig. 7** shows, the whole hand gets pulled in into the threshing drum in the case of an accident, which indicates that 45 cm chute cover length is inadequate to prevent such injuries.

To evolve safer chute parameters, dimensions of forearm, arm length and waist height were used for Indian males. It was observed that the 95th percentile male and female forearm dimension was 443 mm. To restrict hand contact with the threshing drum, the chute cover length has been increased to 650 and chute length to 1000mm. With these changes, the operator's hand to threshing drum contact has been made almost impossible in any working posture. It is recommended that the chute-opening height should be at least 220mm to ensure smooth feeding of crop bundles.

It is proposed that the slope of the feeding shue be increased from 151 to 251 to reduce the probability of injury. Earlier, Thyagraj and Srivastava (1982) indicated that the appropriate tilt angle for the feeding chute was 61. A hand-warning roller has been placed at the end of a baffle plate in the mouth of the chute. This gives a tactile warning to the operator to not push further. It also gives protection to the operator from objects flying towards him from the threshing drum. It is also important that operators be instructed that the chute should always be at elbow level so that it is not possible to bend over it.

Table 2 Thresher feeding system dimensions

Thresher part Dimensions, cm	Percentage of threshers	
	Associated with injuries	In the control sample
Chute length		
<50	0	2
50-60	2	2
60-70	18	7
70-80	23	10
80-90	36	60
>90	21	19
Chute cover length		
<25	23	7
25-30	18	12
30-35	18	17
35-40	11	20
40-45	21	32
>45	9	12
Chute height		
<15	11	8
15-16	35	17
17-18	14	34
19-20	21	19
21-22	14	14
>23	5	8

Conclusion

As 72 % operators work in bending postures, on the basis of the anthropometric dimension of elbow height of the 95th percentile of the Indian male population, a new design of platform is given below. Minimum height difference between stand and chute should be more than 925 mm (100-105 cm). The proposed design changes in thresher chutes will increase thresher cost by approximately Rs. 200 depending upon the size of the thresher. Another risk factor was entanglement in power transmission, which could be easily reduced by making threshers self-propelled, but at increased cost. Thresher injuries result in crush/amputations of upper limbs. Chute design has an important bearing on injuries. Increased chute heights and chute cover lengths are recommended for safer operation. Height of platform and work posture was found to influence the injury outcome. Design modifications of the chute and a height difference of

(continued on page70)

Table 3 Anthropometric dimensions in mm

Percentile	Stature	Forearm	Arm length	Elbow height
95th	1745	443	768	925
50th	1645	418	724	872
5th	1555	395	784	824

Fig. 7 Proposed design of a safer chute thresher

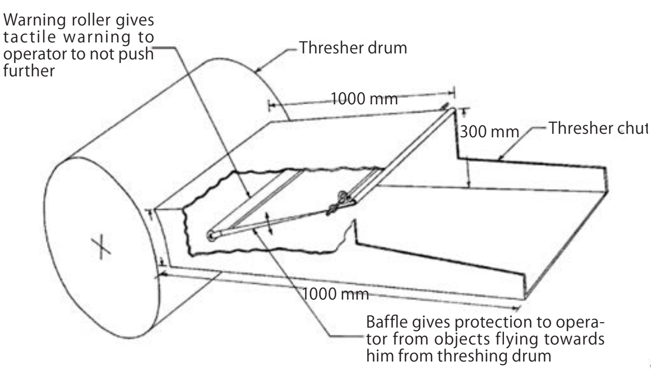
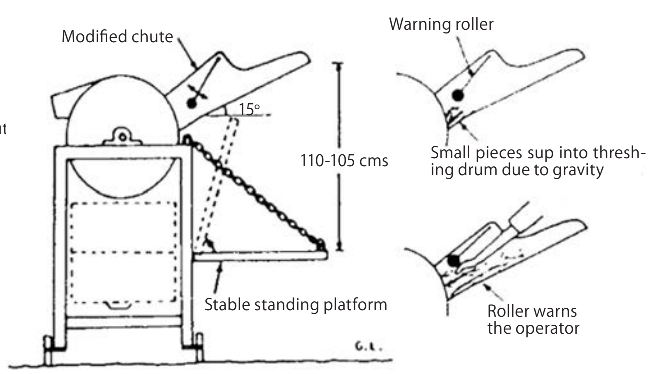


Fig. 8 Safe threshing operation



Study of Kharang Grader in Bhutan

by

Ugyen Drukpa
Assistant Engineer
Agriculture Machinery Centre,
Department of Agriculture,
Ministry of Agriculture,
BHUTAN

Chetem Wangchen
Program Director
Agriculture Machinery Centre,
Department of Agriculture,
Ministry of Agriculture,
BHUTAN

Karma Thinley
Dy. Executive Engineer
Agriculture Machinery Centre,
Department of Agriculture,
Ministry of Agriculture,
BHUTAN

Hai Sakurai
JICA Expert
Agriculture Machinery Centre,
Department of Agriculture,
Ministry of Agriculture,
BHUTAN

Abstract

A power operated kharang grader was developed to alleviate the labor constraint in grading and to produce uniform sizes of kharang (milled maize). The grading was through a 4 mm eccentric shaft rotated to obtain the oscillation in the vertical and horizontal direction. At the optimum operating condition of 540 crank rpm and 15 mm hopper opening, the machine capacity was 330 kg/hr, which was substantially faster than the manual process. The grading efficiency of the machine based on the kharang output was 52 %.

Introduction

The main occupation of the people of Bhutan is agriculture with 69 % of the population of 634,982 depending on it for the livelihood (Population and Housing Census 2005). Cereal crops are mainly comprised of paddy, maize, wheat, barley, millets, buckwheat and oats. On the average 127,125 acres (1 acre = 0.4 hectare) are under cereal crop production. Paddy and maize cultivation continue to be important with 36.34 % and 42.43 % of the actual harvested area, respectively.

Maize is a dry land crop in almost all areas of Bhutan. An area of 53,938 acres is under maize cultivation producing 90,566 metric tons of maize grain in Bhutan. Maize is mostly grown in the eastern region and predominates as the staple food of the people in the eastern region. The overall maize yields increased from 1,005 kg per acre in 2000 to 1,679 kg per acre in 2004 mainly due to the introduction of improved varieties and use of fertilizers (Agriculture Statistics 2004).

Attempts were made by the Royal Government of Bhutan (RGoB) through farm mechanization to alleviate the farm labor constraints and drudgery involved in farming and post harvest operations. One of the interventions was post harvest operation of threshing, milling, grading and storage. These activities were entrusted to the Agriculture Machinery Centre (AMC) by the Royal Government of Bhutan.

Traditionally, farmers in Bhutan mill the maize in a primitive type of indigenous grinding stone. The bottom stone remains stationary and the top stone is rotated manually. A hole is made in the centre from top where the cereal to be ground is fed as shown in the **Fig. 1a**. Ground maize is then graded in different sizes for consumption manually by using the traditional bamboo sieve. Milled and graded maize is called as kharang in Sharchop which is the eastern Bhutanese dialect. The kharang has the size of rice as shown in the **Fig. 1b** and is cooked like rice and eaten with vegetables and meat. Besides kharang, maize can be processed for other value added products for consumption. Maize flake is processed in a flaking machine, called tegma, as shown in **Fig. 1c**. The maize flake is similar to the cornflake and is consumed as snacks and also sold in the local market by the farmers.

The purpose of grading grounded maize is to obtain different sizes, which are used for the different purposes. This traditional method of separating grounded maize for kharang is found to be tedious and time consuming and also inefficient. The sizes obtained by the prototype machine is the same as the size produced by the local farmers. The kharang size ranges from <3 mm to >2 mm and does not have a standard size.

Since maize production is one of the highest in the country, the value added products of maize like kharang and tegma can be promoted and commercialized. In view of this potential, the kharang grader prototype has been developed.

The capacity and grading efficiency of the prototypes is presented for further improvement. The optimum crank revolution and best hopper opening is found using the correlation between and the capacity and kharang output.

Design Concept and Operation Principle

The design concept of the kharang grading machine was based on a similar type of machine used for grading seeds. These types of machines are mostly used in seed processing plants for grading seeds of various sizes. In this grader the oscillation in the vertical direction is utilized for obtaining sieving effects and horizontal oscillation for discharging the material.

The distribution of oscillation force in the vertical and horizontal direction is determined through the angle of attachment of the spring. The connecting rod which is the source of oscillation is placed at a right angle to the leaf spring. This principle was used in the development of the kharang grader, which was fabricated in AMC as shown in the **Fig. 2**.

Mild steel square tube, mild steel angle iron, mild steel sheet, wooden tray wire mesh and an electric motor were used for fabrication. These raw materials were purchased from the neighboring country, India. The main mechanism of this machine is shown below.

Crank Mechanism

The shaft, driven by the 2 HP electric motor, is fixed with a 4 mm offset bushing fitted on the bearing and bearing housing and welded to the connecting crank rod as shown in the **Fig. 3a**. The distance of reciprocation is twice the offset distance, i.e. 8 mm. The crank rod is 20 mm diameter and 255 mm long and is attached to the tray box through a hitch at a right angle to the spring flat. The main connection of tray box and the machine frame is the spring flat. The left hand threaded and right hand threaded is linked with an adjustment nut for the distance adjustment as shown in the **Fig. 3b**.

Tray Box

Three different sizes of wire mesh trays were placed in this box where the material is sieved and discharged as shown in the **Fig. 4a**.

Mesh

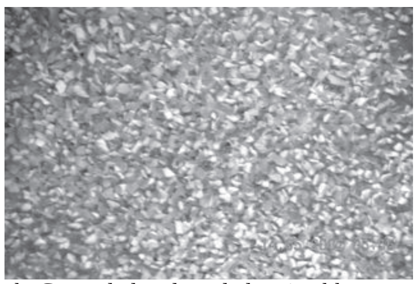
The eye size of the wire mesh was selected as 3 mm at the top, 2 mm in the middle and 1 mm at the bottom as shown in the **Fig. 4c**, **4d**.

Rubber Ball

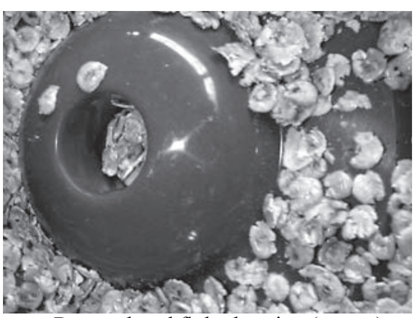
Twenty rubber balls 20 mm diameter were trapped underneath the bottom tray with space to bounce and hit the 1 mm mesh to avoid clogging as shown in the **Fig. 4b**.

Fig. 1 Making of kharang and tegma from maize

a. Indigenous grinding stone



b. Grounded and graded maize kharang



c. Roasted and flaked maize (tegma)

d. Traditional method of grading the kharang

Fig. 2 The kharang grader fabricated and developed in AMC

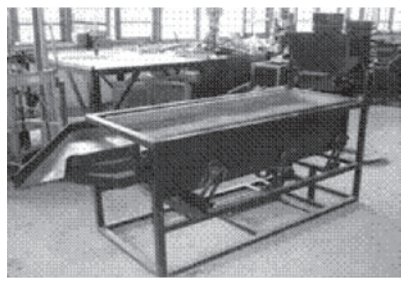
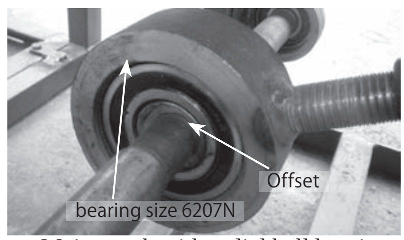
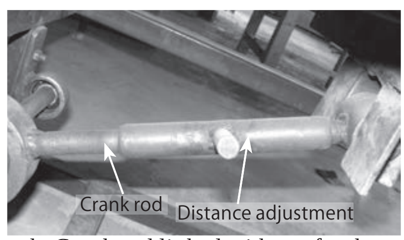


Fig. 3 Main features of the crank mechanism



a. Main crank with radial ball bearing



b. Crank rod linked with nut for the distance adjustment

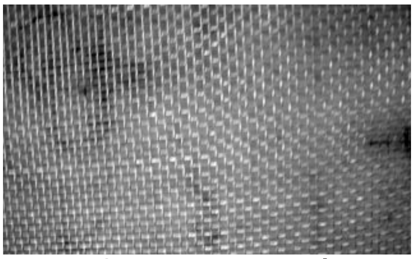
Working Performance Test

Based on the preliminary test, four crank speeds of 520 rpm, 540 rpm, 560 rpm and 580 rpm with two different hopper openings of 10 mm and 15 mm were selected as the experimental parameters. Grading time for each sample and weight of each output were measured to analyze the result of experiment.

Fig. 4 Main features of the kharang grader machine

a. Tray box holding the trays

b. Bottom tray fitted with rubber balls underneath



c. 3 mm square wire mesh

d. Size of tray 1450mmL × 500mmW × 100mmH

Table 1 Experiment showing the different weights of output 2 (kharang) at different crank speeds (rpm) in two hopper openings

A	B	Int. Wt.	Time (sec)	Capacity, kg/h	Output 2	Correlation coefficient
RPM1 (520)	O1 (10 mm)	10	178.17	202.05	1.75	0.49
		10	199.01	180.9	1.92	
		10	189.48	189.99	2.14	
RPM1 (520)	O2 (15 mm)	10	118.17	304.65	2.03	0.89
		10	121.12	297.23	2.05	
		10	115.49	311.72	1.8	
RPM2 (540)	O1 (10 mm)	10	152.27	236.42	1.65	0.79
		10	136.49	263.76	1.76	
		10	194.77	184.83	2	
RPM2 (540)	O2 (15 mm)	10	103.12	349.11	1.79	0.9069
		10	99.03	363.53	1.74	
		10	129.31	278.4	1.63	
RPM3 (560)	O1 (10 mm)	10	139.41	258.23	1.78	0.89
		10	135.28	266.11	1.69	
		10	143.82	250.31	1.79	
RPM3 (560)	O2 (15 mm)	10	91.41	393.83	1.66	0
		10	85.07	423.18	1.65	
		10	84.69	425.08	1.67	
RPM4 (580)	O1 (10 mm)	10	127.09	283.26	1.79	0.87
		10	224.54	160.33	1.73	
		10	161.96	222.28	1.73	
RPM4 (580)	O2 (15 mm)	10	84.03	428.42	1.78	0.27
		10	80.92	444.88	1.77	
		10	81.96	439.24	1.69	

Capacity of the Machine

A 10 kg sample of milled maize was graded into four sub grades using three sieve sizes stacked upon each other at two different feed gate openings with four workable crank speeds (rpm). The time taken to grade the sample and weigh the output 2 (kharang) were recorded to get the best correlation between the capacity of the machine and the output 2. Three repeated trials were made and the result recorded in **Table 1**. Based on the results from the **Table 1**, 540-rpm crank speed and a hopper opening of 15 mm were correlated with the value of 0.9069. This was the best combination and resulted in a machine capacity of 330 kg/hr. The result was based on the output 2. The optimum grading capacity could not be determined by the time taken for one cycle of grading because, with the higher crank rpm and larger opening, the discharge from the top sieve was faster without being graded. This resulted in decreased weight of output 2, output 3 and output 4.

From the highest correlation value, the capacity of the machine was calculated by the average weight obtained from three replications by the following **Table 1**.

Grading Efficiency of the Machine Based on the Output 2

Based on the result from **Table 1** at 540 rpm of the crank and 15

Table 2 Results of weight obtained from the experiment (Table 1) with a crank speed of 540 rpm and hopper opening of 15 mm

Int. Wt.	Output 2	Residual
Pre determined weight	2.625	
15	2.577	1.268
15	2.577	1.249
15	2.659	1.265
15	2.618	1.203
Total	10.431	4.985
Avg	2.60775	1.24625

mm hopper opening, a pre-weight sample from different outputs were mixed to get a sample of 15 kg each. The samples were graded at 540 rpm with 15 mm hopper opening. Four trials were made and weight and time required for grading were recorded. Output 2 was further graded to get the purity of the output. The data were recorded and following formulae were used.

Grading efficiency = (Q2-q2)/w2 ....(1)

Where,

Q2 is Average weight of the output 2, kg

q2 is weight of the impurities mixed which has been graded from output 2, kg

w2 is pre weight of output 2 before mixing, kg

Q2... 2.607 kg

Q2... 1.246 kg

W2... 2.625 kg

Em... 52 %

From the result in the **Table 2** and equation (1), it was found that the grading efficiency of the machine is 52 %.

Conclusion and Recommendation

The percentage of the kharang from the milled maize varied for the type of milling machine. However, the grading percentage was accurate and much faster compared to the traditional method.

Although the machine was primarily for grading kharang, it could also grade other products like fine flour sieved from the 1 mm sieve. Therefore, a crank speed of 540 rpm with hopper opening distance of 15 mm was selected for the machine.

- The grading efficiency of this machine needs to be further tested by repeating the operation for the each product from the trays.
- Further development for the blower to remove the scale needs to be attached in the next modification.
- The study of kharang size in Bhutan needs to be carried out to standardize the size of the kharang in near future.
- In order to improve the grading efficiency of the machine, further study is needed.

REFERENCES

Test Codes & Procedures for Agriculture Machinery. 1995. Regional Network for Agriculture Machinery (RNAM) .

Agriculture Statistics. 2004, Department of Agriculture, Ministry of Agriculture, Royal Government of Bhutan

Bevan, Thomas. 1984. Theory of Machines, third edition. Population and housing census. 2005.

Visvanathan, R. 1994. Krishi Vigyan Kendra, Kattupakam 603203, India. On development of a hand operated rotary sieve cleaner cum grader for sesame seed. Vol. 25 No.2. Agricultural Mechanization in Asia, Africa and Latin America.

■■

Biomass Utilization for Thermal Energy

by
Gürkan A. K. Gürdil
Department of Agricultural Machinery,
Ondokuz Mayıs University,
55139 Samsun,
TURKEY
e-mail: ggurdil@omu.edu.tr

Jan Malaták
Technical Faculty,
Czech University of Agriculture in Prague,
CZECH Republic

K. Çagatay Selvi
Department of Agricultural Machinery,
Ondokuz Mayıs University,
55139 Samsun,
TURKEY

Yunus Pinar
Department of Agricultural Machinery,
Ondokuz Mayıs University,
55139 Samsun,
TURKEY

Abstract

With the depletion of fossil energy sources in sight, the importance of renewable sources of energy becomes one of the major conditions for permanently sustainable development not only in agriculture, but also in society as a whole. The main purpose of this paper is to provide necessary information about energy production of heat processed from agricultural wastes.

Sixteen analyses of selected mixed wastes were carried out, especially in pellet form, in the framework of this research project. Each analysis was followed by stoichiometric calculations as well as by chemical composition and energy balance. According to the results, the most important factors are sulphur nitrogen and chlorine quantity in wastes, because of their influence on the final values of emissive concentrations. The main task of current activities in the research field is to find ways of decreasing air pollution.

Introduction

The importance of renewable energy resources, such as biomass, has increased because of the predicted depletion of fossil energy sources. It is becoming one of the main conditions for sustainable development, not only in the agriculture but also in society as a whole. It has been declared that the worldwide share of vegetable biomass (mostly wood) use has increased by about 8 % over the past 20 years, in the sense of general consumption of prime power sources (OEI, 2004). This growth is common only in developing countries, where wood is often the only source of energy, especially in rural areas. In some countries (e.g. Ethiopia, Pakistan, Nigeria) four fifths of mined wood is used as fuel. However the fuel wood consumption is increasing in developed countries as well (McBurney, 1995; CIGR, 1999; Malaťák, et al., 2005).

The share of energy from renewable resources should reach 30 % of total energy consumption within next 50 years. The share of energy from renewable resources should be raised from the current 6 % to 12 % in EU countries by the year 2010. The biomass share of renewable energy sources is currently about 60 % and its growth to a share of 80 % is expected (OEI, 2004). It is planned to alter one fifth of the fuel consumption by alternative fuels in the EU. It will reduce crude oil supply dependency and will lead to improvement in atmosphere quality (Pastorek, et al., 1999; Váňa, 2002).

Increasing the share of renewable energy sources became the priority of EU energy programs. It led to research financing in a framework of large integrated projects. The major European energy equipment and vehicle manufacturers were also involved in this action (Toke, 2006).

Wood pellets are an environmentally friendly biofuel with no net contribution to global warming. Today, the demand for wood pellets for residential heating is rapidly increasing in Sweden and in many other countries. Therefore, alternative raw materials for pellet production, such as wheat straw and peat, are of great interest. Before these new fuels are widely used, it is important to study their emissions into air during combustion. The smoke contains a large number of compounds which can affect both health and the environment to varying degrees (Olsson, 2006).

Emission problem are mostly concerned with the ideal combustion of fuels. There are certain ways of decreasing emissions, such as continuous dosing of fuel, maintaining a high level of temperature in a combustion chamber input to secondary, even tertiary air, and choice of optimal fuel humidity (Price, 1998; Malaťák, et al., 2004).

The kind and form of the biomass as well as the type of plant cause different qualities of energy output and compositions of emissions. Conversion technology for the combustion of wood is extensively well engineered, whereas the use of other biomass such as straw or sewage sludge, especially for gasification, is insufficiently approved. Therefore, it is necessary to investigate an appropriate procedure for the use of biomass (Osowski and Fahlenkamp 2006).

Industrially made stem wood pellets of pine and spruce sawdust were found to have small differences in their combustion characteristics. Variations in combustion characteristics of pellets are discussed in relation to the composition of raw material (Rhen et al., 2006).

Polluting substances (solid, liquid and gaseous) have a negative influence on the atmosphere directly or after chemical or physical changes in the surrounding air. These substances also harm the health of people and other organisms. The most important polluting substances are SO_2, CO, CO_2, and NO_x (Gürdil, 1998; Pastorek et al., 1999; Malaťák et al., 2004; ČNI, 2005).

Stoichiometry analysis of combustion processes is useful in estimating the characteristics of fuels, which are very important to solve problems that arise during the designing stage, as well as within a work control of current combustion arrangement. The first step for any stoichiometry calculations of fuels and a thermal work operation of combustion equipment is an elemental analysis of fuel. Elemental analysis is very important for all of stoichiometry analysis, thermal effectiveness and losses in combustion equipment. It also influences the thermal work of combustion equipment. So-called elemental analysis is used during the detection of solid fuels to estimate the weight percentage of carbon (C), hydrogen (H), oxygen (O), sulphur (S), nitrogen (N) and water content of the fuel (Pastorek et al., 1999; Malaťák et al., 2004).

Carbon, H and O are the main components of solid biofuels and are of special relevance for gross calorific value. H is of special relevance also for net calorific value. Fuel N content is responsible for NO formation. NO emissions are the main environmental impact factors of solid biofuel combustion. Cl and S are responsible for deposit formation and corrosion and are therefore relevant for high plant availability. Furthermore, Cl causes HCl as well as polychlorinated dibenzo-dioxin and furans (PCDD/F). S and SO emissions are involved in the formation of aerosols (submicron particle emissions). Ash content influences the choice of the appropriate combustion technology and influences deposit formation, fly ash emissions and logistics concerning ash storage and ash utilization/disposal (Obernberger et al., 2006).

The study of 'biomass utilization for thermal energy' has worldwide importance due to rapid increase in fuels used and interest in renewable energy sources, in particular agricultural wastes. The definite determination of typical physical-chemical properties is necessary for designing, building and checking of combustion equipment and for the thermal use of agricultural wastes.

Material and Method

When using agricultural wastes as biomass for energy production, it is necessary to emphasize plant operation values. It is necessary to provide chemical composition, operating parameters, ash matter and stoichiometric calculations and then final values of the individual combustion components. Ash matter is a solid residue obtained by the ideal burning of solid fuel at a temperature of 800 ± 25 ºC in an oxidising atmosphere.

All solid fuels in natural (raw) form are composed of three main components: total water content, ash matter and combustibles. This composition can be expressed by the following formula:

$$\sigma(W_t) + \sigma(C_t) + \sigma(H_t) + \sigma(O_t) + \sigma(S_t) + \sigma(N_t) + \sigma(A_t) = 100\ \% \quad \text{.............................(1)}$$

where: $\sigma(W_t)$, $\sigma(C_t)$, $\sigma(H_t)$, $\sigma(O_t)$, $\sigma(S_t)$, $\sigma(N_t)$, $\sigma(A_t)$ are weight parts of total water, C, H, O, S, N and ash amount in the original sample in % [weight].

Water and ash are the non flammable parts of fuel, described as ballast or deadwood. Both decrease the fuel heating power. Their presence immediately influences the construction of combustion equipment and they are often referred to as sources of problems during operations (ČNI, 2001).

The flammable part of the fuel consists of C, H and S. Only C, H and S are involved in the exothermic reaction with air oxygen-autogenous burning. The oxygen present in fuel work as an oxidant and the N is the only part that is not involved in burning.

Component analysis, stoichiometric analyses and evaluation of parameters of selected wastes were carried out on compressed or loosely spread agricultural wastes. The materials were compressed into different shapes by using various pressures.

Compressed materials were also used in the form of pellets produced with an average pressure of 80 MPa. Uncompressed biofuels require too much space and volume; hence transportation, manipulation and storage costs increased. During combustion, fast ignition and transmission of a small amount of specific heat occur. On the other hand, parameters of compressed biofuels are advantageous, and these fuels last longer in the hearth during combustion in comparison to uncompressed fuels.

Materials were obtained from agricultural companies and farms. The biofuels used in this research were (1) black coal and slack coal (reference sample) and brown coal and nut 2 (reference sample) obtained from a mine; (2) bark from poplar pellets 10 mm diameter and wood chips obtained from a heating plant; (3) cereal straw, reed, energy sorrel, hay and grass obtained from a farm; (4) rapeseed straw and cereal cleaning residues obtained from a storehouse; (5) cocoa bean shell obtained from a company; (6) ekobiopal obtained from a biogas station; (7) fermented waste treatment mud obtained from a water cleaning station; and (8) meat and bone meal obtained from a rendering plant. For the comparison of selected fuels, two reference fuels (numbers 1 and 2) were chosen (**Table 1**).

A furnace with 15 kW power was used for the measurements. It had an automatic burning system for burning pellets and loose materials and also it enabled emissions to be measured. Generally, a larger furnace was used for this process but, the choice of a smaller furnace was to determine the suitability for domestic and commercial use. Thus, 15 kW power was chosen as a representative furnace for smaller power units. Pellets were brought to the heating chamber with a helical feeder and extruded step by step. Emission results of pellets from combustion equipment were obtained at 11 % oxygen level. Temperature of burnt gas varied around 188.5 ºC. Emission concentrations of smoke gas were determined by an analyzing device.

Elemental analyses were carried out for selected wastes to set the basic parameters of fuels; water content in % [weight], ash in % [weight], volatile and nonvolatile combustibles in % [weight], combustion heat in $MJ.kg^{-1}$, heating power in $MJ.kg^{-1}$, carbon C in % [weight], $CO_{2\ max}$. in % [volume], hydrogen H in % [weight], nitrogen N in % [weight], sulphur S in % [weight], oxygen O in % [weight] and chlorine Cl in % [weight]. Fixed elemental analyses were carried out by an elemental analyzer.

Table 1 Elemental analyses values of selected agricultural wastes

	Type	Water content, % [weight]	Ash matter, % [weight]	Heat power, $MJ.kg^{-1}$	Carbon C, % [weight]	Hydrogen H, % [weight]	Nitrogen N, % [weight]	Sulphur S, % [weight]	Oxygen O, % [weight]	Chlorine Cl, % [weight]
		W_t	A	Q_i	C_t	H_t	N_t	S_t	O_t	Cl_t
1	Black coal - slack coal (reference sample)	15.44	17.76	20.56	54.21	3.34	0.78	3.09	5.38	0.014
2	Brown coal - nut 2 (reference sample)	20.76	20.44	15.79	42.31	4.24	0.58	3.85	7.81	0.025
3	Bark from poplar pellets, 10 mm	8.52	3.33	16.18	43.7	4.98	0.13	0.04	39.28	0.02
4	Cereal straw and reed in a ratio 1:1 pellets, 10 mm	5.64	8.14	15.65	41.95	5.71	0.68	0.09	37.65	0.14
5	Cereal straw and rapeseed straw in a ratio 1:1 pellets, 15 mm + treacle	7.66	7.27	15.08	42.24	5.99	0.95	0.14	35.55	0.20
6	Cereal straw and energy sorrel in a ratio 1:1 pellets, 10 mm	5.02	7.48	15.95	41.88	5.35	0.65	0.12	39.4	0.10
7	Cereal straw and energy sorrel in a ratio 1:1 pellets, 10 mm	5.29	6.74	16.10	42.96	5.42	0.67	0.11	38.7	0.11
8	Cereal straw pellets, 10 mm	7.31	3.99	16.53	46.54	5.71	0.19	0.09	35.97	0.20
9	Cereal straw pellets, 20 mm	8.54	8.49	14.97	41.56	5.15	0.64	0.07	35.55	-
10	Cereal cleaning residues and energy sorrel in a ratio 1:1 pellets, 20 mm	10.69	5.59	14.69	42.57	6.44	1.36	0.21	33.01	0.10
11	Cereal cleaning residues as pellets, 8 mm	8.33	6.49	16.25	42.62	6.48	3.67	0.16	32.05	0.20
12	Cereal cleaning residues and grass in a ratio 1:1 pellets, 20 mm	8.49	9.50	15.04	41.02	5.95	1.44	0.13	33.37	0.10
13	Cocoa bean shell	5.81	8.04	16.86	38.79	5.39	1.96	0.24	39.75	0.02
14	Cocoa bean shell pellets, 20 mm	7.18	13.10	14.04	41.73	5.86	2.32	0.10	29.63	0.08
15	Ekobiopal as pellets, 10 mm	8.04	12.12	15.64	42.47	4.9	1.18	0.28	31.01	-
16	Fermented waste of mud and hay in a ratio 1:1 pellets, 10 mm	6.39	18.61	9.85	37.80	3.88	1.85	0.77	29.58	0.12
17	Fermented waste of mud and energy sorrel in a ratio 1:1 pellets, 20 mm	11.16	11.80	13.77	39.56	5.76	1.39	0.55	29.66	0.12
18	Meat and bone meal and energy sorrel in a ratio 1:1 pellets, 20 mm	8.86	12.39	15.94	42.82	6.53	4.79	0.48	23.89	0.24

The following parameters were set by calculations:

1. fuel thermal energy,
2. oxygen amount (air) necessary for ideal combustion,
3. amount and composition of flue gases and
4. specific weight of flue gases.

Agricultural waste heating power is set by calculation based on measured combustion heat and elemental analyses. Combustion heat is measured by calorimeters. The relationship between combustion heat Q_s and heating power Q_i can be described as follows (ÚNM, 2001):

$$Q_i = Q_s - (0.02442 \times 1000) \times \{\sigma (W_t) + 8.94 \times \sigma (H_t)\}, \text{ in kJ.kg}^{-1} \quad \text{...........................(2)}$$

where: Q_i is heating power in $kJ.kg^{-1}$, Q_s is combustion heat in $kJ.kg^{-1}$, $\sigma (W_t)$ is water content of the analyzed sample in %, 8.94 is recalculation of hydrogen coefficient, $\sigma (H_t)$ is hydrogen content of analyzed sample in % and 0.02442 is a constant value responding to the energy used for heating 1 % of water at 25 ºC (ÚNM, 2001).

All of the stoichiometric calculations were calculated by the weight of total water amount contained in selected samples. Values were also calculated by the air surplus coefficient for normal conditions (by the temperature t = 0 ºC and a pressure p = 101.325 kPa) as well as for the reference oxygen amount of combustibles Q_r = 11 %.

Results

The results of the analyses carried out for the selected wastes in order to set the basic parameters of fuels are shown in **Table 1**.

The most important factors for the thermal use of fuels are water and ash matter contents. Water content value contained in wastes fluctuated from 5.02 weight % in the case of cereal straw and energy sorrel to up to 11.16 weight % for fermented sediments with the biomass and energy sorrel mixture. There are obvious possibilities of different fuel use based on water content and heating. The other inflammable element is ash matter. The ash matter content is low (**Table 1**). Plant trash has a lower (about 86 %) content of ash matter than brown coal. It has the following positive effects. The amount of solid ash particles emission during burning is less, and also the amount of solid residue generated is significantly less. The smallest amount of ash matter was obtained by burning the bark from poplar pellets. However, the highest amount was obtained by burning fermented sediments with biomass. These large fluctuations of water content and ash matter are significant qualities of selected wastes. Final heat values are shown in Table 1. It mostly concerns volatile and nonvolatile combustibles, C, N, O, and often-discussed Cl amount. These fluctuations of fuel compositions influence their use as well as combustion equipment settings. However, the Cl amounts of reference samples were not taken into consideration. The accuracy in elemental analyses was 99%.

From the stoichiometric analyses of selected wastes (**Table 1**), differences between air consumption and the amount of produced dry emissions were found.

The most significant emission factors are S and Cl amounts, contained in selected wastes. A perceptible increased N emission is observed in mixed wastes based on plant biomass. These energy plants have higher concentrations of N in the fuel, which causes their limited use. Also, most of Cl comes to the vapor phase during combustion. This element causes HCl emission and the possible production of PCDD/F. On the other hand, Cl and its combustion products have a corrosive effect on the combustion equipment and heating elements.

Sulphur changes to the vapor phase as SO_2 or SO_3. In the case of biomass combustion equipment, S emission is not a problem with respect to the limiting values (**Tables 1** and **2**). A decisive factor is the corrosive action of S. Final values of each flue gas component are mentioned in **Table 2**. Final combustion values reach the optimum of combustion parameters.

Discussion

The choice and design of combustion equipment is influenced by fuel stoichiometry and other fuel parameters such as heating power, water content and energy density.

Analyses of selected samples confirmed a wide range of N, S and Cl concentrations in the wastes. Oxygen is a problematic part of the fuel because of H and partly C binding, creating hydrated oxides, water and other oxides. Oxides are mainly connected with N (in the form of amines and proteins contained in fuels) and Cl. Chlorine oxides interact with conversion equipment and especially with combustion equipment.

The most limiting factors for the thermal use of analyzed wastes are amounts of water and ash matter (**Table 1**). From the tested samples of agricultural wastes, better parameters have been found in samples number 3, 4, 5, 6, 7, 8, 9, 10, 11 and 13, due to their considerable amount (up to 9 % [weight]) of ash matter (ČNI, 2005).

As can be seen from Table 1, pellets from fermented waste of mud and hay in a 1:1 ratio with a water content of 6.39 % [weight] (sample number 16) had relatively low heat parameters in comparison with other samples. The mixture of fermented waste treatment mud and hay in a 1:1 ratio is not recommended for further use because of its low heating power and large amounts of ash matter. On the contrary, good results were achieved in the sample 17 with fermented waste treatment mud and energy sorrel.

Water content in wastes ranged

from 5.02 % [weight] in cereal straw and energy sorrel mixture (sample number 6) up to 11.16 % [weight] of total water in fermentation sediments with biomass and energy sorrel mixture (sample number 17). To improve heat quality in samples 10 and 17, it was necessary to reduce the content of all water during combustion. Other samples had optimum water content (from 8 to 10 % [weight]) in firing; they could be used as fuel for combustion equipment without further adjustments (**Table 1**).

The ash matter content was low, as can be seen from elemental analyses. Plant residues have a lower content of ash matter than the reference samples number 1 and 2 (**Table 1**). A criterion for ash matter content in biomass is 9 - 13 % [weight] (Jevič, et al., 2005). It had the following positive effects: the amount of solid ash particles emission during burning was smaller and the amount of solid residues was also significantly smaller. The smallest amount of ash was obtained by burning bark pellets from poplar pellets (sample number 3). The highest amount was obtained by burning fermentation sediment with biomass (sample number 16). A significant increase of N emission could be seen in the mixed wastes based on plant biomass (**Table 2**). The amount of N in fuels increased the nitrogen concentration, so-called fuel N. Then this fuel N reacted with O and forms NO_x, which is not a benign gas. These energy plants had higher values of nitrogen in the fuel, especially in sample 18 (**Table 1**), due to their limited use.

Another component of wet-burnt gas is increased emission of CO_2 (sample 3). Reducing these emissions would mean interference (alteration in air supply for firing) to the combustion equipment. From the results, it can be seen that except for the sample 16 (a high content of ash and low heat output), other samples provide requirements for environmental combustion; therefore, it is possible to recommend them for the utilization of thermal energy (**Table 1**).

Conclusion

It is necessary to obtain ideal burning conditions during the combustion process for agricultural waste use such as alternative fuels for combustion equipment. Therefore, it is necessary to burn only fuels with a specified structure, type and quality.

Table 2 Final values of the individual combustion components

	Sample	Volume amount of wet burnt gas elements in % [volume]					Volume amount of burnt gas elements in $m^3.kg^{-1}$				
		CO_2	SO_2	H_2O	N_2	O_2	v_{CO2}	v_{SO2}	v_{H2O}	v_{N2}	v_{O2}
1	Black coal - slack coal (reference sample)	6.41	0.13	7.32	73.11	12.17	1.01	0.02	1.15	11.52	1.92
2	Brown coal - nut 2 (reference sample)	5.84	0.19	9.09	72.03	11.99	0.79	0.03	1.23	9.73	1.62
3	Bark from poplar pellets, 10 mm	7.22	0.002	9.474	70.7	11.77	0.81	0.004	1.06	7.969	1.327
4	Cereal straw and reed in a ratio 1:1 pellets, 10 mm	6.78	0.01	9.74	70.85	11.79	0.78	0.00	1.12	8.17	1.36
5	Cereal straw and rapeseed straw in a ratio 1:1 pellets, 15 mm + treacle	6.54	0.01	9.96	70.86	11.79	0.79	0.00	1.2	8.52	1.42
6	Cereal straw and energy sorrel in a ratio 1:1 pellets, 10 mm	7.04	0.01	9.56	70.78	11.78	0.78	0.00	1.06	7.84	1.31
7	Cereal straw energy sorrel in a ratio 1:1 pellets, 10 mm	6.98	0.01	9.47	70.91	11.8	0.80	0.00	1.08	8.12	1.35
8	Cereal straw pellets, 10 mm	6.77	0.00	9.32	71.21	11.86	0.87	0.00	1.19	9.11	1.52
9	Cereal straw pellets, 20 mm	6.90	0.00	9.68	70.79	11.78	0.77	0.00	1.09	7.93	1.32
10	Cereal cleaning residues and energy sorrel in a ratio 1:1 pellets, 20 mm	6.24	0.01	10.3	70.83	11.78	0.79	0.00	1.31	9.00	1.50
11	Cereal cleaning residues as pellets, 8 mm	6.19	0.01	10.05	71.11	11.81	0.80	0.00	1.29	9.12	1.52
12	Cereal cleaning residues and grass in a ratio 1:1 pellets, 20 mm	6.42	0.01	10.08	70.87	11.79	0.76	0.00	1.20	8.43	1.40
13	Cocoa bean shell	6.97	0.02	10.08	70.4	11.7	0.72	0.00	1.04	7.29	1.21
14	Cocoa bean shell pellets, 20 mm	6.32	0.01	9.67	71.31	11.85	0.78	0.00	1.19	8.77	1.46
15	Ekobiopal as pellets, 10 mm	6.80	0.02	9.19	71.29	11.86	0.79	0.00	1.07	8.29	1.38
16	Fermented waste of mud and hay in a ratio 1:1 pellets, 10 mm	6.26	0.03	10.24	70.85	11.78	0.74	0.00	1.21	8.34	1.39
17	Fermented waste of mud and energy sorrel in a ratio 1:1 pellets, 20 mm	6.26	0.06	9.81	71.2	11.83	0.52	0.01	0.81	5.89	0.98
18	Meat and bone meal and energy sorrel in a ratio 1:1 pellets, 20 mm	5.85	0.02	9.79	71.62	11.88	0.80	0.00	1.33	9.77	1.62

The most limiting factor for the heat use of the tested agricultural waste is water and ash matter content. Fuel composed of mixture of fermented sewage disposal plant sediments and hay in 1:1 ratio is not suitable because of its heat parameters.

Samples 3, 9, 11, 12, 15 and 18 had optimum water content (8-10 % [weight]). Plant residues had a lower content of ash matter than the reference samples number 1 and 2. Only sample 16 (18.61 % [weight]) had higher ash amount than the reference sample 1. The samples 12, 15, 17 and 18 had optimum ash matter that varied from 9 to 13 % [weight]. Maximum thermal energy output was obtained from sample 13 (cocoa bean shell) (16.86 $MJ.kg^{-1}$). Minimum thermal energy was obtained from the sample number 16 (9.85 $MJ.kg^{-1}$). Except for sample 16, other samples had similar thermal energy as compared to the reference samples 1 and 2.

The sample of fermented waste of mud and hay in a ratio 1:1 had a higher content of sulphur than other samples and had increased emission concentrations. Sulphur emissions of the other tested samples were not a problem, as to the trace amounts.

The solution leads to emission reduction and to reduction of environmental pollution. Determination of typical physical-chemical properties of fuel wastes and their classification will increase their use in market.

Definition of typical physical-chemical properties of selected samples from agricultural waste can be used as the initial data for material and thermal-chemical use. It is necessary for designing, building and checking of combustion equipment and for the thermal use of agricultural wastes.

REFERENCES

CIGR. 1999. Handbook of Agricultural Engineering, Volume V. Energy and Biomass Engineering. ASAE St. Joseph, Michigan, USA, 126-145.

ČNI, ČSN 44 1310. 2001. Tuhá paliva - Označování analytických ukazatelů a vzorce přepočtů výsledků na různé stavy paliva. ČNI Praha, Czech Republic, 6-14.

ČNI, ČSN CEN/TR 14980. 2005. Tuhá alternativní paliva–Zpráva o vzájemném rozdílu mezi biologicky rozložitelnými a biogenními složkami tuhých alternativních paliv.. Prague, Czech Standards Inst., Czech Republic, 2-11.

Gürdil, G. 1998. Confined Space Hazards: Air Contaminants in Livestock House. International Scientific Seminars: New Knowledge in Technological Equipment and in Agricultural Operations. Czech University of Agriculture Prague, 13-15.

Jevič, P., P. Hutla, Z. Šedivá, and M. Přikryl. 2005. Třídění kvality a specifikace tuhých biopaliv. 4. Zemědělská technika a biomasa 2005. VÚZT Praha, Mze ČR, ISBN 80-86884-07-4, 120-126.

Malaťák, J., R. Brož, D. Plíštil, J. Karanský, and M. Dvořák. 2005. Thermal Properties of Phytomass. VII. International Conference of Young Scientists, Czech University of Agriculture Prague, Technical Faculty, 136-141.

Malaťák, J., D. Plíštil, M. Přikryl, and P. Jevič, 2004. Stoicheiometric Characteristics of Biomass. International Conference of Science: Technical Instruments and Technological Procedures of Processing Primary Commodities for Food Industry and Rational Assessing of the Waste Products, DTEB, TF, CUA Prague Czech Republic, 53-58.

McBurney, B. 1995. A Case Study of a Large Scale Wood Waste Power Generating Plant. Biologue-Regional Biomass Energy Program Report. The Official Publication of the National BioEnergy Industries Association, Vol.13 (1). 5-11.

Obernberger, I., T. Brunner, and G. Barnthaler. 2006. Chemical Properties of Solid Biofuels-Significance and Impact. Biomass & Bioenergy 30 (11): Pergamon-Elsevier Science LTD, England, ISSN: 0961-9534, 973-982.

OEI, Outstanding Environmental Issues. 2004. A Review of the EU's Environmental Agenda. RIVM Bilhoven, Netherlands, NUR 940, ISBN 90-6960-117-6, 57.

Olsson, M. 2006. Wheat Straw and Peat for Fuel Pellets. Organic Compounds from Combustion. Biomass & Bioenergy 30 (6). Pergamon-Elsevier Science LTD, England, ISSN: 0961-9534, 555-564.

Osowski, S. and H. Fahlenkamp. 2006. Regenerative Energy Production Using Energy Crops. Industrial Crops and Products 24 (3), Elsevier Science BV, Netherlands, ISSN: 0926-6690, 196-203.

Pastorek, Z., J., Kára, P. Hutla, D. Andert, V. Sladký, A. Jelínek, and P. Plíva, 1999. Využití odpadní biomasy rostlinného původu. VÚZT Praha, Czech Republic, 25-49.

Price, B. 1998. Electricity from Biomass. Financial Times Energy, England, ISBN 1-84296-109-8, 14-36.

Rhen, C., M. Ohman, R. Gref, and I. Wasterlund. 2006. Effect of Raw Material Composition in Woody Biomass Pellets on Combustion Characteristics. Biomass & Bioenergy 31 (1). Pergamon-Elsevier Science LTD, England, ISSN: 0961-9534, 66-72.

Toke. 2006. Renewable Financial Support Systems and Cost Effectiveness. Journal of Cleaner Production. 15 (3). Elsevier SCI LTD, England, ISSN: 0959-6526, 280-287.

ÚNM, ČSN 44 1352. 2001. Stanovení spalného tepla a výpočet výhřevnosti. ÚNM Praha, Czech Republic, 10-12.

Váňa, J. 2002. Problémy brzdící rozvoj energetického využívání fytomasy. ISBN: 80-86555-16-X, Praha, Czech Republic, 5-7.

■■

ABSTRACTS

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

721

Influence of Blade Geometry on Efficiency of Experimental Cotton Stalk Shredder: T. Senthilkumar, Asstant Professor, Krishi Vigyan Kendra, Vamban Pudukkottai - 622 303, INDIA; **R.Manian,** Professor Dept. of Farm Machinery, AEC & RI TNAU, Coimbatore-641 003, INDIA; **K. Kathirvel,** Professor, same.

The influence of the selected level of variables of three levels of number of blades viz. 2, 3 and 4, four levels of peripheral velocity viz. 21.52, 23.80, 26.58 and 28.60 ms^{-1}, three levels of blade thickness of 2, 4 and 6 mm and four levels of blade rake angle of 0, 15, 30 and 45 deg on shredding efficiency in terms of length of cut of cotton stalk was investigated. The revealed that increase in peripheral velocity from 21.52 to 28.60 ms^{-1} resulted in decreased length of cut. The lowest value of length of cut of 113.83 mm was observed at the shredder with 2 blades, 0 deg blade rake angle and 28.60 ms^{-1} peripheral velocity. At 0 deg blade rake angle, the length of cut of shredded cotton stalk was much lower than other blade rake angles at 6mm blade thickness. Increase in number of blades from 2 to 4 resulted in increased length of cut for all the levels of blade rake angle. Increase in blade rake angle from 0 to 45 deg resulted in increased length of cut for all the levels of peripheral velocity and number of blades. 2 blades with 0º blade rake angle, 6 mm blade thickness and 28.60 ms^{-1} peripheral velocity recorded lowest value of length of cut than other combinations.

841

Quality of Teaching Faculty in Private Sector of Higher Education in Pakistan as Viewed by Administrators, Teachers and Students: Abdul Majeed Khan, University Institute of Education and Research, University of Arid Agriculture, Rawalpindi, PAKISTAN

The major purpose of this paper was to examine the quality of teaching faculty in private sector of higher education in Pakistan as viewed by administrators, teachers and students by adopting descriptive method of research. As the study was conducted at national level, the population of the study constituted 270 administrators, 6,180 teachers and 61,108 students in existing 54 private universities and degree awarding institutions of Pakistan. Method of cluster sampling was used to select the study sample of 840 people, which was carried out in two stages. At the first stage, 12 clusters of universities were randomly chosen out of the total population of the private universities. At the second stage, 60 administrators, 180 teachers and 600 students were selected through random sampling procedure with five administrators, 15 teachers and 50 students from each selected cluster. Three questionnaires (one each for administrators, teachers and students), developed and refined through pre-testing, were used as measuring instruments to collect data. The resarcher personally visited each university and collected data from the sample. The collected data was tabulated, analyzed and interpreted by using ANOVA technique. It was concluded that all respondents were found to have positive opinion about the encouragement of teachers for students class participation, teachers' ability to create conducive class environment for learning and wholesome attitude of teachers toward their students. Nevertheless, they expressed slightly negative opinion about the professional training of teachers, teachers' command over the subject matter, teachers' encouragement in promoting critical and creative thinking among students.

■■

NEWS

On Indian Engineers Day on September 15, 2009 Dr. Gajendra Singh was conferred Eminent Engineer Award for the year 2009 by the Institution of Engineers (India) for significant contribution to the advancement and application of practice of Engineering in India.

Dr. Singh is recipient of American Society of Agricultural and Biological Engineers' Kishida International Award and Massey-Ferguson Educational Gold Medal Award; Emil Mrak International Award by the University of California at Davis; and Gold Medal by the Indian Society of Agricultural Engineers. He has served as the founding Vice Chancellor, Doon University, Dehradun; Vice President for Academic Affairs of the Asian Institute of Technology, Bangkok, Thailand; and Deputy Director General (Engineering) of the Indian Council of Agricultural Research (ICAR), New Delhi.

Prof. Singh served as the Founding President of the Asian Association for Agricultural Engineering from 1990 to 1995.

Every year, The Institution of Engineers (India) organizes Engineers Day on 15th September to commemorate the birth anniversary of Bharat Ratna Sir M Visvesvaraya. The event is marked by organisation of lectures, programmes, round table discussion etc by various centres of the Institution.

On this occasion, Delhi State Centre of the Institution of Engineers (India) confers Eminent Engineering Personalities with "Eminent Engineer Award" for their distinguished services in Engineering Profession.

■■

Co-operating Editors

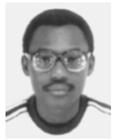

B Kayombo


M F Fonteh


A A K El Behery


A M El Hossary


B S Pathak


R J Bani


I K Djokoto


D K Some


K Houmy


J C Igbeka


E U-Odigboh


K C Oni


L U Opara


N G Kuyembeh


A H Abdoun


A B Saeed


A I Khatibu


E A Baryeh


S Tembo


H A Cetrangolo


I de A Nääs


A E Ghaly


E J Hetz


A A Valenzuela


R Aguirre

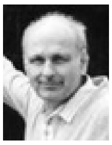

O Ulloa-Torres


S G C Magana


H Ortiz-Laurel


W J Chancellor


M R Goyal


A K Mahapatra

G R Quick

S M Farouk

Daoulat Hussain

M A Mazed

Chetem Wangchen

Wang Wanjun

S Illangantileke

S M Ilyas

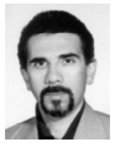
A M Michael

G Singh

T P Ojha

S R Verma

Soedjatmiko

M Behroozi-Lar

Saeid Minaei

J Sakai

B A Snorbar

C J Chung

C C Lee

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

William J. Chancellor
Professor Emeritus, Bio. and Agr. Eng. Dept., Univ. of California, Davis, CA, 95616, U.S.A.
TEL+1-530-753-4292, FAX+1-530-752-2640
E-mail: wjchancellor@ucdavis.edu

Megh R. Goyal
Prof./Agric & Biomedical Engineering, University of Puerto Rico, P.O.Box 5984, Mayaguez PR, 006815984, U.S.A., TEL+1-787-265-4702
E-mail: m_goyal@ece.uprm.edu

Ajit K. Mahapatra
Present add: Agric. & Biosystems Eng. Dept., South Dakota State Univ., P.O. Box2120 Brookings, SD 57007-1496, U.S.A., TEL605-6885291, FAX 605-6886764, E-mail: mahapata@sdstate.edu

-ASIA and OCEANIA-

Graeme R. Quick
Consulting Enginner, 83 Morrisons Road, Peachester, Queensland, 4519, AUSTRALIA

Shah M. Farouk
Professor (Retd.),Farm Power & Machinery Dept., Bangladesh Agricultural University, Mymensingh 2200, BANGLADESH, TEL+880-91-5695ext.2596, FAX91-55810, E-mail: smf@bdcom.com

Daulat Hussain
Dean, Faculty of Agric. Engineering and Technology, Bangladesh Agricultural University, Mymensingh-2202, BANGLADESH, TEL+880-91-52245, FAX91-55810, E-mail: dhussain@royalten.net

Mohammed A. Mazed
Member-Director, Bangladesh Agri. Res. Council, Farmgate, Dhaka, BANGLADESH
E-mail: mamazed@barcbgd.org

Chetem Wangchen
Programme Director Agricultural Machinery Centre Ministry of Agriculture Royal Government of Bhutan, Bondey Paro Bhutan 1228, BHUTAN, E-mail: krtamc@druknet.bt

Wang Wanjun
Past Vice Director and Chief Engineer/Chinese Academy of Agricultural Mechanization Sciences, 1 Beishatan, Beijing, 100083, CHINA
TEL+86-(0)83-001-6488-2710, FAX001-6488-2710
E-mail: wwj@isp.caams.org.cn

Sarath Illangantileke
Regional Representative for South and West Asia, International Potato Center (CIP), Regional Office for CIP-South & West Asia, IARI (Indian Agric. Res. Institute) Campus, Pusa, New Delhe-12, 110002, INDIA, TEL+91-11-5719601/5731481, FAX./5731481, E-mail: cip-delhi@cgiar.org

S. M. Ilyas
Director, National Academy of Agricultural Research Management (NAARM), Rajendranagar, Hyderabad-500030, INDIA, Tel+91-40-24015070, Fax:+91-41-24015912, E-mail: smiyas@sity.com

A. M. Michael
1/64, Vattekunnam, Methanam Road, Edappally North P.O., Cochin, 682024, Kerala State, S. INDIA

Gajendra Singh
Professor, Gajendra Singh, Former Vice Chancellor, Doon University 260, SFS Flats, Ashok Vihar Phase IV, Delhi-110052 INDIA, TEL+91-11-2730 7664, Email: gajendrashinghb@gmail.com

T. P. Ojha
Director General(Engg.) Retd., ICAR, 110, Vineet Kung Akbarpur, Kolar Road, Bhopal, 462 023, INDIA
TEL+91-755-290045

S. R. Verma
Prof. of Agr. Eng, & Dean Eng.(Retd), 14, Good Friends Colony, Barewal Road , Via Ayoli Kalan, Ludhiana 142027 Punjab, INDIA, TEL+91-(0)161-463096
E-mail: srverma@hotmail.com

Soedjatmiko
President, MMAI(Indonesian Soc. of Agric. Eng. & Agroindustry), Menara Kadin Indonesia Lt.29 Jl. HR. Rasuna Said X-5/2-3 Jakarta, 12940, INDONESIA
TEL+62-(0)21-9168137/7560544, FAX(0)21-527448 5/5274486/7561109

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

Saeid Minaei
Assistant Professor, Dept. of Agr. Machinery Eng., Tarbiat Modarres Univ., P.O.Box 14115-111, Tehran, IRAN
TEL+9821-6026522-3(office ext.2060, lab ext.2168)
FAX+9821-6026524, E-mail: minaee7@hotmail.com

Jun Sakai
Professor Emeritus, Kyushu University, 2-31-1 Chihaya, Higashi-ku, Fukuoka city, 813, JAPAN
TEL+81-92-672-2929, FAX+81-92-672-2929
E-mail: junsakai@mtj.biglobe.ne.jp

Bassam A. Snobar
Professor and Vice President, Jordan University of Science and Technology, P.O.Box 3030 Irbid, 22110, JORDAN, TEL+962-2-295111, FAX+962-2-295123
E-mail: snobar@just.edu.jo

Chang Joo Chung
Emeritus Professor, Seoul National University, Agricutural Engineering Department, College of Agriculture and Life Sciences, Suwon, 441-744, KOREA
TEL+82-(0)331-291-8131, FAX+82-(0)331-297-7478
E-mail: chchung@hanmail.net

Chul Choo Lee
Mailing Address: Rm. 514 Hyundate Goldentel Bld. 76-3 Kwang Jin Ku,Seoul, KOREA
TEL+82-(0)2-446-3473, FAX+82-(0)2-446-3473
E-mail: ccsslee@chollian.net

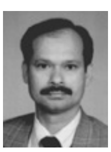
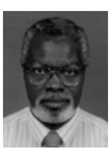
Muhamad Zohadie Bardaie
Professor, Department of Agricultural and Biosystems Engineering, University Putra Malaysia, 43400 upm, Serdang, Serdangor, MALAYSIA
TEL+60-3-89466410
Email: zohadie@eng.upm.edu.my

Madan P. Pariyar
Consultant, Rural Development through Selfhelp Promotion Lamjung Project, German Technical Cooperation. P.O. Box 1457, Kathmandu, NEPAL

David Boakye Ampratwum
Associate Professor, Dept.of Bioresource and Agricultural Engineering, College of Agriculture, Sultan Qaboos University, P.O. Box 34, Post Code 123, Muscat, Sultanate of Oman, OMAN
TEL+968-513866, FAX513866
E-mail: davidamp@squ.edu.om

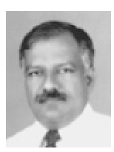
EITag Seif Eldin
Mailling Address: Dept. of Agric. Mechanization, College of Agriculture, P.O. Box 32484, Al-Khod, Sultan Qaboos University, Muscat, Sultanate of Oman, OMAN

Allah Ditta Chaudhry
Professor and Dean Faculty of Agric. Engineering and Technology, University of Agriculture, Faisalabad, PAKISTAN


M Z Bardaie

M P Pariyar

D B Ampratwum

E S Eldin

A D Chaudhry

A Q Mughal

R ur Rehmen

B T Devrajani

N A Abu-Khalaf

Surya Nath


R M Lantin


R P Venturina

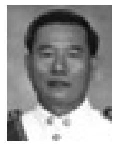

S A Al-Suhaibani


A M S Al-Amri


S F Chang

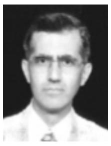

T S Peng

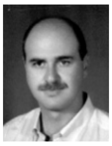

S Krishnasreni


S Phong-supasamit


C Rojanasaroj


V M Salokhe


Y Pinar


I Haffar

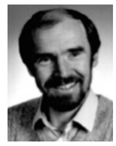

N Hay


P V Lang


A A Hazza'a


A P Kaloyanov


P Kic


H Have


J Müller


G Pellizzi


W B Hoogmoed


Jan Pawlak


O S Marchenko


J Kilgour


M Martinov

Back Issues

(Vol.38, No.3, Summer, 2007-)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol.39, No.3, Summer, 2008)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol.39, No.4, Autumn, 2008)

◇ ◇ ◇

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA
(Vol.40, No.1, Winter, 2009)

■■

INSTRUCTIONS TO AMA CONTRIBUTORS

The Editorial Staff of the AMA requests of articles for publication to observe the following editorial policy and guidelines in order to improve communication and to facilitate the editorial process:

Criteria for Article Selection

Priority in the selection of article for publication is given to those that –

a. are written in the English language;
b. are relevant: to the promotion of agricultural mechanization, particularly for the developing countries;
c. have not been previously published elsewhere, or, if previously published are supported by a copyright permission;
d. deal with practical and adoptable innovations by, small farmers with a minimum of complicated formulas, theories and schematic diagrams;
e. have a 50 to 100-word abstract, preferably preceding the main body of the article;
f. are printed, double-spaced, under 3,000 words (approximately equivalent to 6 pages of AMA-size paper) ; and those that
g. art: supported by authentic sources, reference or bibliography.
h. written on floppy disc or CD-R

Rejected/Accepted Articles

a. As a rule, articles that are not chosen for AMA publication are not returned unless the writer(s) asks for their return and are covered with adequate postage stamps. At the earliest time possible, the writer(s) is advised whether the article is rejected or accepted.
b. When an article is accepted but requires revision/modification, the details will be indicated in the return reply from the AMA Chief Editor in which case such revision/modification must be completed and returned to AMA within three months from the date of receipt from the Editorial Staff.
c. "The AMA does not pay for articles published. However, the writers are given collectively 5 free copies (one copy air-mailed and 4 copies sent by surface/sea mail) of the AMA issue wherein their articles are published. In addition, a single writer is given 25 off-prints of the article and plural writers are given 35 off-prints (also sent by surface/sea mail)"
d. Complimentary copies: Following the publishing, three successive issue are sent to the author(s).

Procedure

a. Articles for publication (original and one-copy) must be sent to AMA through the Co-operating Editor in the country where the article originates. (Please refer to the names and addresses of Co-operating Editors in any issue of the AMA). However, in the absence of any Co-operating Editor, the article may be sent directly to the AMA Chief Editor in Tokyo.
b. Contributors of articles for the AMA for the first time are required to attach a passport size ID photograph (black and white print preferred) to the article. The same applies to those who have contributed articles three years earlier. In either case, ID photographs taken within the last 6 months are preferred.
c. The article must bear the writer(s) name, title/designation, office/organization, nationality and complete mailing address.

Format/Style Guidance

a. Article must be sent on 3.5 inch floppy disk or CD-R with MS DOS format (e.g. Word Perfect, Word for DOS, Word for Windows... **Absolutely necessary TEXT FORMAT**) along with two printed copy (A4).
b. The data for graphs and the black & white photographs must be enclosed with the article.
c. Whether the article is a technical or popular contribution, lecture, research result, thesis or special report, the format must contain the following features:
(i) brief and appropriate title;
(ii) the writer(s) name, designation/title, office/organization; and mailing address;
(iii) an abstract following ii) above;
(iv) body proper (text/discussion);
(v) conclusion/recommendation; and a
(vi) bibliography
d. The printed copy must be numbered (Arabic numeral) successively at the top center whereas the disc copy pages should not be number. Tables, graphs and diagrams must likewise be numbered. Table numbers must precede table titles, e.g., "Table 1. Rate of Seeding per Hectare". Such table number and title must be typed at the top center of the table. On the other hand, graphs, diagrams, maps and photographs are considered figures in which case the captions must be indicated below the figure and preceded by number, e.g., "Figure 1. View of the Farm Buildings".
e. **The data for the graph must also be included. (e.g. EXCEL for Windows)**
f. Tables and figures must be preceded by texts or discussions. Inclusion of such tables and figures not otherwise referred to in the text/discussion must be avoided.
g. Tables must be typed clearly without vertical lines or partitions. Horizontal lines must be drawn only to contain the sub-title heads of columns and at the bottom of the table.
h. Express measurements in the metric system and crop yields in metric tons per hectare (t/ha) and smaller units in kilogram or gram (kg/plot or g/row).
i. Indicate by footnotes or legends any abbreviations or symbols used in tables or figures.
j. Convert national currencies in US dollars and use the later consistently.
k. Round off numbers, if possible, to one or two decimal units, e.g., 45.5 kg/ha instead of 45.4762 kg/ha.
l. When numbers must start a sentence, such numbers must be written in words, e.g., Forty-five workers..., or Five tractors..."instead of 45 workers..., or, 5 tractors.

INQUIRY and REQUEST to AMA

Please let us know your need. We shall promptly reply them. Inquire on any catalog listed in the advertisement in this issue. We shall try our best to serve you.

We welcome articles of interest to agricultural mechanization.

FIll in the reverse side of this card and send us by sealed letter.

FARM MACHINERY INDUSTRIAL RESEARCH CORP.

7-2 Kanda nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan

ADVERTISED PRODUCYS INQUIRY

Product	Advertiser	Vol., No., Page

EDITORIAL REQUEST TO AMA

Your Name :

Address :

Occupation :

SUBSCRIPTION/ORDER FORM

AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA (AMA)

Issued Quarterly

Subscription Rate (includes surface mail postage)

Annual (4 issues)........................... ¥.6,000
Single copy...................................... ¥.1,700

Back Issues (1971-75, ¥.2,000 per copy)
(1976-77, ¥.1,200 per copy)
(1978-80, ¥.1,500 per copy)

★ Spring, 1971
★ Vol.2 Autumn, 1971
☐ Vol.3 No.1, 1972
☐ Vol.3 No.2, Summer, 1972
★ Vol.4 No.1, Spring, 1973
☐ Vol.4 No.2, Autumn, 1973
★ Vol.5 No.1, Summer, 1974
☐ Vol.6 No.1, Spring, 1975
★ Vol.6 No.2, Autumn, 1975
☐ Vol.7 No.1, Winter, 1976
☐ Vol.7 No.2, Spring, 1976
☐ Vol.7 No.3, Summer, 1976
☐ Vol.7 No.4, Autumn, 1976
☐ Vol.8 No.1, Winter, 1977
☐ Vol.8 No.2, Spring, 1977
☐ Vol.8 No.3, Summer, 1977
☐ Vol.8 No.4, Autumn, 1977
☐ Vol.9 No.1, Winter, 1978
☐ Vol.9 No.2, Spring, 1978
★ Vol.9 No.3, Summer, 1978
★ Vol.9 No.4, Autumn, 1978
☐ Vol.10 No.1, Winter, 1979
☐ Vol.10 No.2, Spring, 1979
☐ Vol.10 No.3, Summer, 1979
☐ Vol.10 No.4, Autumn, 1979
★ Vol.11 No.1, Winter, 1980
★ Vol.11 No.2, Spring, 1980
☐ Vol.11 No.3, Summer, 1980
☐ Vol.11 No.4, Autumn, 1980
★ : Indicates issues out of stock.

☐ **Abstract and Index, 1971-80(Special Issue, 1983)**

(Check issues and number of copies you wish to order)

Back Lssues from 1981, ¥.1,700 per copy (Vol. 12 No.1 and No.4 are out of stock)
Abstract and Index, Special Issue, 1983, ¥.2,000 per copy.

Vol.______No. _____, _____________ ,________copy / copies

(Check one)
☐ Please invoice me/us
☐ I/We enclose remittance for ¥.__________

****

Name: ____

Firm: ____

Position: ____

Address: ____
(block letters)

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
7-2 Kanda-Nishikicho, Chiyoda-ku, Tokyo 101-0054, Japan
Tel. (03)-3291-3674

STAMP

FARM MACHINERY INDUSTRIAL RESEARCH CORP.
7-2 Kanda Nishikicho, Chiyoda-ku,
Tokyo 101-0054, Japan

1st FOLD HERE

2nd FOLD HERE