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EDITORIAL

The report, "The Limits to the Growth", presented by The Club of Rome in 1972 became the world topic at that time. The report concluded that, if the present growth trend in world population, industrialization, pollution, food production and resource depletion continue unchanged, the limits to growth on this planet will be reached some time within the next one hundred years. It suggested that mankind find a sustainable way of living with the limited resources and environment. This concern proved to be realistic in the 21st century.

Oil price exceeded one hundred U.S. dollars/barrel this year and there is a concern about continuing rise. Since the U.S. President Bush announced a new energy policy that encouraged production of bio-ethanol from corn, alcoholization of corn has become a profitable business, partly because of rising oil prices. This caused a steep rise in corn price of more than two and half times for two years. Many wheat and soybean fields have changed to cornfields, which also caused the price of wheat to triple and soybeans to double as compared to the price six months ago. Such a steep rise in grain price for a short period is a historical event.

China and India, having been called developing countries, have entered a phase of aggressive economic growth. In China, an increasing number of wealthy people pushed up the consumption of oil, fats and meat as well as grain. Due to large, new demand for grain, China will import more food than any other country in the world.

Because of the two reasons mentioned above, new food demand in developing countries and food utilization for bio-energy, global balance of grain supply and demand will to be lost. Such terms as biomass energy utilization, ethanolization and bio-diesel became the hottest key words to be used as the topic of conferences and symposia throughout the world.

I have been involved in agricultural machinery business since 1965 and have seen a recognizable change in agriculture in developed countries from grain over supply to short supply. Rising grain prices should be glad tidings for farmers who have suffered low grain price for a long time. I have insisted that the price of agricultural products has been unreasonably low. The present trend of higher grain prices may encourage young farmers to stay in farming.

The average corn yield in China is about five tons per hectare, which is half of that in the U.S. How to raise the productivity to the U.S. level is their big challenge. It is also important from the global point of view to raise corn productivity in China by increasing mechanization of corn production.

I was elected President of the Asian Association of Agricultural Engineering (AAAE) for 2008-2009 at their international conference in Bangkok last December. I accepted it because, in my opinion, various global issues will never be solved if the people in Asia with the world's largest population will not work toward the solution of their own problems by themselves. Population, agriculture, energy, water and environment are our particular concerns. Asian people must work toward its solution. Since agricultural engineers will play a key role there, AAAE will be able to have a leading part in achieving the objective. I wish to do what little I can as the President of AAAE. Any advice from AMA readers is welcome.

Farm mechanization will make historical progress in the 21st century. We, agricultural machinery experts, must work together toward the solution to many global issues.

Yoshisuke Kishida
Chief Edior

Tokyo, Japan
February 2008

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AGRICULTURAL MECHANIZATION IN ASIA, AFRICA AND LATIN AMERICA

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Performance Comparisions of Tractor Tire Configurations on Concrete Surface

by

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Abstract

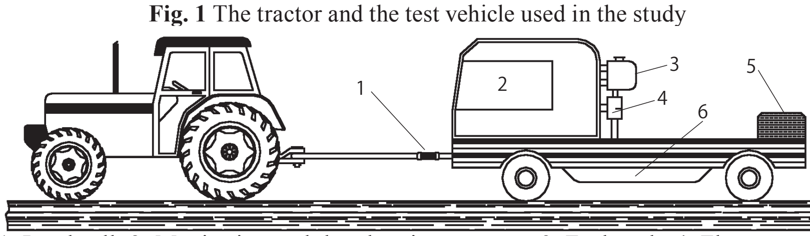
Effects of tire ply construction (radial and bias-ply) and tire arrangement (singles and duals on the rear axle) on the performance of a medium-powered tractor were evaluated on a concrete surface for three gear levels. Performance evaluations were identified in terms of maximum drawbar pull, maximum drawbar power, overall tractor efficiency, and specific fuel consumption. The use of radial tires provided a small advantages on the evaluation criteria compared to the bias tire. The use of dual tires instead of single tires and the increase of ground speed provided considerable advantages with respect to the evaluation criteria, particularly on the maximum drawbar power. The best results in this study were obtained with radial tires and dual configuration at the highest speed level used in the study. In this configuration, the maximum drawbar power and overall tractor efficiency increased by about 12 % and 4 %, respectively, while specific fuel consumption decreased by about 4 %.

Introduction

The tractor is mostly used as a power source for pulling agricultural machinery on farms. Engine power has to be efficiently converted to useful drawbar power. This necessity can be fulfilled using convenient tires and arrangements. Approximately 12-18 % of the engine power output is lost before it reaches the tractor's axle (Sabanci, 1997). Another important portion of the loss (20-40 %) occurs between the axle and the ground (Mowitz and Finck, 1987). Since increasing the tractive performance is the key for operational and cost effective practices, appropriate tire selection and arrangement should be investigated for different working conditions. Many researchers have focused on this subject and carried out numerous studies on different surfaces. Hutching (1983) carried out field experiments with single and dual tractor tires. He concluded that there was little difference between the performances of the dual and single tires when ballasted to the same level. Gee-Clough et al. (1977) performed traction tests on 17 different surfaces by using radial and bias-ply tires with the same dimensions. They found that the radial-ply tires gave an average of 5-8 % increase in the Dynamic Traction Ratio (DTR) at 20 % slip. Kraving (1986) sumed up the advantages of the radial tires over the bias-ply tires such as increased tire footprint, additional tractive efficiency, reduced wheel slip, smoother ride in field, and improved fuel economy.

The number of tractors in the economic tractor park in Turkey, (aged up to 15 years) is about 550,000 (Sumer et al., 2003). Only approximately 1 % of the tractors have a PTO (Power-take-off) power of 70 kW or higher. Also, the share of the tractors within the power range of 60-69 kW is about 3 % (Sumer et al., 2004). The tractors used in Turkish farms are often insufficient during some farm operations that require relatively higher drawbar pull such as combined tillage, deep plowing, and subsoiling. This problem can partial-

Fig. 1 The tractor and the test vehicle used in the study



1: Load cell, 2: Monitoring and data logging systems, 3: Fuel tunk, 4: Flowmeter, 5: Ballast, 6: Braking system ly be prevented by using appropriate tire construction and arrangements. In general, previous researchers used high-powered tractors (> 100 kW) in their studies. However, the Turkish farmers use relatively low-powered tractors (< 60 kW) since they have smaller farm sizes and low purchasing power. Therefore, there is a need for a study to determine the appropriate tire configuration for low-powered tractors used in Turkey.

In this study, the performance of a medium-powered, mechanical front wheel drive (MFWD) tractor was examined based on overall tractor efficiency, specific fuel consumption, maximum drawbar pull, and maximum drawbar power. Tire configurations with singles versus duals on the rear axle were studied. Also, bias ply tires versus radial ply tires that are not commonly used in Turkey were investigated. Experiments were carried out on concrete, which was a comparison surface.

Objectives

The objective of this study was to compare the performance of a medium-powered MFWD tractor with different tire configurations at different speeds on concrete surface for the benefit of farmers and tractor dealers.

Procedure

The experiments were performed on a concrete test course at the Agricultural Machinery Test Laboratory (AMTL) of the Department of Agriculture located in Ankara, Turkey. A New Holland 80-66 mechanical front wheel drive (MFWD) tractor with a PTO power of 63 kW, which was considered as a high-powered tractor in Turkey, was used in the experiments. The test vehicle of the AMTL was attached to the tractor and used for the measurement of the performance criteria (**Fig. 1**).

The experiments were established with three factors based on a randomized complete block design with four replications as shown below:

- tires (bias-ply and radial-ply tires),
- tire arrangement (single and dual tires), and
- gear levels (II-1, I-4 and II-2).

The singles, experiments were conducted with 150 kg ballasts on each tire rim on the rear axle and 300 kg ballast in front of the tractor. The tractors in the power range of 60-69 kW are sold with ballasts (total 300 kg) attached on the rear axle in Turkey. The tractors are used with these ballasts in most of the agricultural operations. As an alternative to ballast use with singles, experiments were also conducted with duals on the rear axle. A mounting apparatus, which provided 10 cm spacing between the tire sidewalls (**Fig. 2**), were designed and fabricated for dual tire arrangement on the rear axle. The commonly accepted inflation pressure of the outer tires was 14 kPa (2 psi) less than that of inner tires. Kraving (1986) reported that this practice resulted in less stress on the outer tire, axle, and mounting apparatus.

Singles and duals were separately examined by using bias and radial-ply tires on concrete for three different gear levels. Details of the tires and the tests are furnished in **Table 1**. Tractors in Turkey within the power range of 60-69 kW are generally equipped with the tires in the sizes selected in this study (**Table 1**).

In all tests, the tractor was loaded with the test vehicle until the maximum drawbar pull was obtained with selected gear levels at 15 % slip. The

Fig. 2 Mounting apparatus fabricated for the study

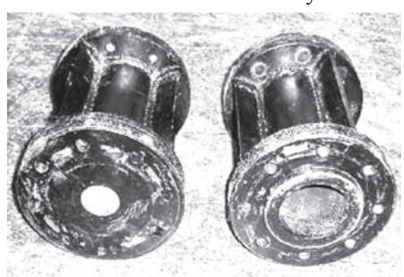


Fig. 3 The effects of interactions on maximum drawbar pull (S-Single, D-Dual, B-Bias, R-Radial, G-Gear)

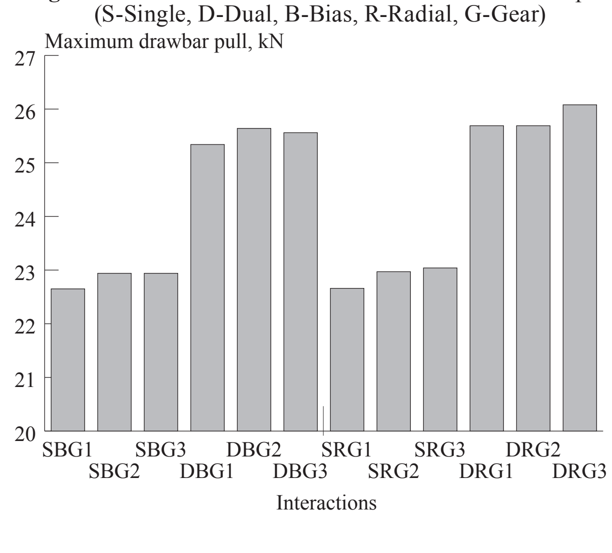
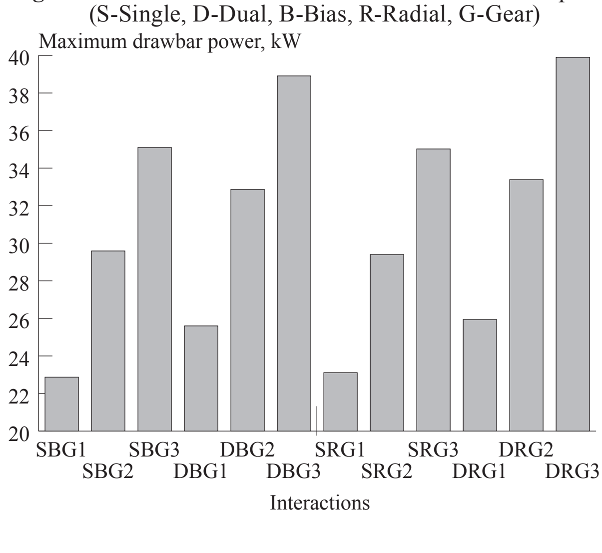


Fig. 4 The effects of interactions on maximum drawbar power (S-Single, D-Dual, B-Bias, R-Radial, G-Gear)



tractor was operated at full throttle in each selected gear level. The wheel slip was controlled by the method constituted by the American Society of Agricultural Engineers (ASAE, 1987). This method used ratios between engine speed, tractor's rear tire revolution, and PTO-revolution. The slip was also measured with a digital slip measurement system and compared with slip values that were determined by using the ASAE method. Tractor's maximum drawbar pull, ground speed, and fuel consumption were measured for each tire configuration. Maximum drawbar power, overall tractor efficiency, and specific fuel consumption were calculated from the measured parameters.

Tractor performance is generally evaluated by using TE (tractive power/axle power) and DTR (tractive force/dynamic axle load) criteria. This study used maximum drawbar pull, maximum drawbar power, overall tractor efficiency, and specific fuel consumption since these are more objective comparison parameters for farmers and farm managers.

The overall tractor efficiency (n) was calculated using the following equation (Sabanci, 1997; Macmillan, 2002):

$$\eta = \frac{N_D}{N_F} \quad \text{..(1)}$$

where,

N_D = maximum drawbar power (kW),

N_F = fuel power (kW).

Maximum drawbar power (ND) and fuel power (NF) was calculated from the equations (2) and (3), respectively:

$$N_D = P \bullet V \quad \text{....................................(2)}$$

$$N_F = \frac{B \bullet H}{3600} \quad \text{....................................(3)}$$

where,

P = Maximum drawbar pull (kN),

V = Ground speed (m/s)

B = Fuel consumption (kg/h),

H = Energy value of diesel fuel (41,870 kJ/kg).

Results and Discussion

Variance analysis was performed to determine the effects of factors on the maximum drawbar pull, maximum drawbar power, overall tractor efficiency, and specific fuel consumption. Results of the variance analysis indicated that the three factors had statistically significant effects on all evaluation criterions ($P < 0.01$). Then, the criteria were examined with all possible triple interactions due to their practical and meaningful results. Graphs were presented for each evaluation criterion versus triple interactions.

Maximum drawbar pull increased 0.07 % on the average with radials compared to bias, 12.2 % with duals compared to singles, and 1.3 % with G3 (II-2) compared to G1 (II-1). The highest maximum drawbar pull, obtained with DRG3 interaction, was 26.7 kN on the average, while the lowest maximum drawbar pull, obtained with SBG1 interaction, was 22.7 kN on the average (**Fig. 3**). This represented an average 15 % increase with the DRG3 interaction compared to SBG1. The tire arrangement was markedly more effective than the tire construction and the ground speed on the maximum drawbar pull. It was observed that the dual arrangement considerably increased the maximum drawbar pull (**Fig. 3**).

Maximum drawbar power increased 1.0 % on the average with radials compared to bias, 12.4 % with duals compared to singles, and 48.6 % with G3 (II-2) compared to G1 (II-1). Ground speed had principal influence on maximum drawbar power because it is a function of power as seen in equation (2). Gear level was the most important variable. For instance, AMTL (1997) reported that maximum drawbar power of a New Holland 80-66 MFWD tractor with I-2 (2.45 km/h) gear level instead of II-1 (3.61) increased by 58 % at 15 % slip. The highest maximum drawbar power

Fig. 5 The effects of interactions on specific fuel consumption (S-Single, D-Dual, B-Bias, R-Radial, G-Gear)

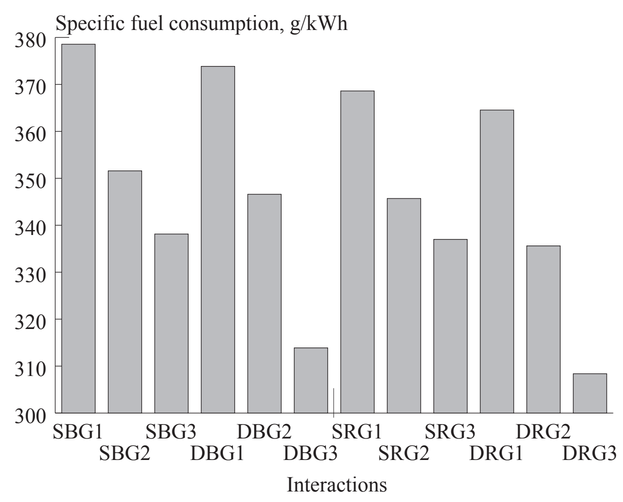


Table 1 Details of the tires and tests

Tires and ballasting, Regular tread (R-1)	Rear axle	
	Singles	Duals
Bias-ply		
Front: 12.4/11 x 24	138 kPa (20 psi)	138 kPa (20 psi)
Rear: 18.4/15 x 30	111 kPa (16 psi)	111 kPa (16 psi)[a]
Radial-ply		
Front: 12.4/11 x 24	124 kPa (18 psi)	124 kPa (18 psi)
Rear: 18.4/15 x 30	97 kPa (14 psi)	97 kPa (14 psi)[b]
Tractor Weight	4,290 kg	4,255 kg
Static weight distribution		
Front	40 %	40 %
Rear	60 %	60 %

Gears: G1, II-1 (3.65 km/h); G2, I-4 (4.60 km/h); G3, II-2 (5.50 km/h); Surface: Concrete test cource

[a]Inner rear bias-ply tire inflation pressure. Outer rear bias-ply tire inflasion pressure was 97 kPa (14 psi).

[b]Inner rear radial-ply tire inflation pressure. Outer rear radial-ply tire inflasion pressure was 83 kPa (12 psi).

was obtained in DRG3 interaction as 38.5 kW, while the SRG1 interaction provided the lowest maximum drawbar power as 22.9 kW (**Fig. 4**). This represented an average 68.5 % increase with the DRG3 interaction compared to SRG1 interaction. It was observed that the ground speed considerably increased the maximum drawbar power (**Fig. 4**).

Specific fuel consumption decreased 2.0 % in average with radials compared to bias, 3.6 % with duals compared to singles, and 12.6 % with G3 (II-2) compared to G1 (II-1). The highest specific fuel consumption was obtained in SBG1 interaction as 378.5 g/kW-h, while the lowest specific fuel consumption was 308.4 g/kW-h with DRG3 interaction (**Fig. 5**). Compared to the SBG1 interaction, the DRG3 interaction reduced the specific fuel consumption by 18.5 % on the average. The most significant factor in this reduction was the increase in the ground speed. Fuel consumption values increased markedly depending on the increase in the ground speed and the use of duals (**Fig. 6**). However, the specific fuel consumption values decreased at the same conditions (**Fig. 5**) because drawbar power increased with the increase in the ground speed and with the use of duals (**Fig. 4**).

The overall tractor efficiency increased 2.0 % in average with radials compared to bias, 4.1 % with duals compared to singles, and 14.7 % with G3 (II-2) compared to G1 (II-1). The highest overall tractor efficiency was obtained in DRG3 interaction as 27.3%, while the lowest overall tractor efficiency was 22.6 % with SBG1 interaction. This represented an average 22.7 % increase with the DRG3 interaction compared to SBG1.

The ground speed provided considerable advantage on performance evaluation criteria except maximum drawbar pull, since the ground speed is a function of drawbar power, and drawbar power is an important parameter for calculating the overall tractor efficiency and specific fuel consumption.

Various studies have compared the tractive performance of radial-ply and bias-ply tires with different arrangements. Radial ply-tires were found to cause significant increased in average pull when run in the 0-30 % slip range (Forrest et al., 1962; Vanden and Reed, 1962). Hausz (1985) stated that the tractive advantages of radial-ply tires resulted from their deflection characteristics and resulting pressure distribution. This was because the lugs on the radial-ply tire (near the center of tread) have a much more uniform pressure distribution, and will bite into the soil more uniformly. Taylor et al. (1976) compared the tractive performances of a radial-ply and a bias-ply tire of the same size and shape in a range of soil conditions. Their results showed that the radial-ply tires had little advantage in terms of tractive efficiency. Other researchers stated that radial-ply tires were more durable than bias-ply tires on firm soil. Hoffman (1983) reported that the tractive efficiency values increased by 8-9.5 % with the use of radial-ply tires instead of bias-ply tires on different soils. Grisso et al. (1992) reported that firm soil conditions reduced the advantages of radial tires.

Bashford et al. (1987) conducted field experiments with single and dual tractor tires. They concluded that the use of dual tires instead of single tires provided little advantage in terms of tractor performance on wheat stubble surfaces. Clark and Liljedahl (1969) compared single and dual tires, and concluded that the performance of the dual tires was better than that of the single tires in soft soil. In firm soil, however, there was no significant different between the two arrangements. McLeod et al. (1969) reported that dual tires gave generally better tractive performance than single tires, but the difference was less pronounced in clay soil than in sandy soil.

Fig. 6 The effects of interactions on fuel consumption (S-Single, D-Dual, B-Bias, R-Radial, G-Gear)

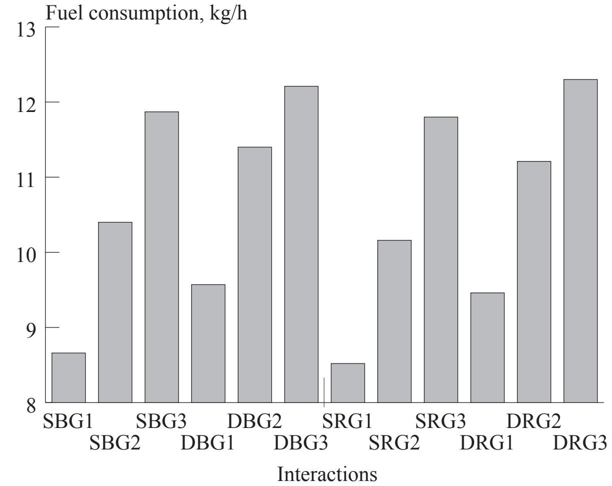
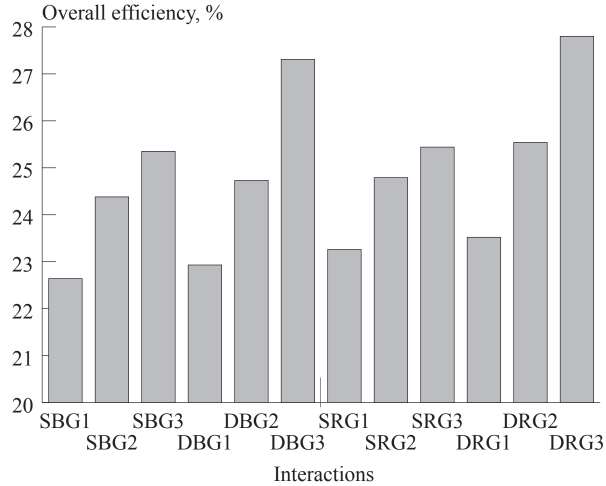


Fig. 7 The effects of interactions on overall tractor efficiency (S-Single, D-Dual, B-Bias, R-Radial, G-Gear)



The results reported in this study were in general agreement with other relevant research. However, there are some differences in increase and decrease ratios determined for definite working conditions. These differences might result from diversities in working conditions and performance evaluation parameters.

Conclusions

Maximum drawbar power and overall tractor efficiency increased by about 12 % and 4 %, respectively, in the case of operating with duals instead of singles, while specific fuel consumption decreased by about 4 %. The increase of ground speed provided significant advantages on maximum drawbar pull, overall tractor efficiency, and specific fuel consumption. The best results in this study were obtained in II-2 gear level (G3, 5.5 km/h) with dual configuration. Highest maximum drawbar power, maximum drawbar pull, overall tractor efficiency, and lowest minimum specific fuel consumption were determined by DRG3 interaction.

Dual arrangement considerably increased the drawbar power in this study. It was concluded that duals could be useful in terms of farm economy since the agricultural operations requiring relatively higher power (such as deep plowing, combined tillage, and subsoiling) can be completed on time with the increase of drawbar power and using machines with bigger working width.

The mounting apparatus designed and fabricated in this study can be easily and securely adopted for duals arrangement for Turkish agricultural conditions.

Radial tire use provided a slight advantage over bias tire. Grisso et al. (1992) reported that firm soil conditions reduced the advantages of radial tires. The authors think that carrying out the experiments on concrete surface reduced the advantages of the radial tires in this study.

Acknowledgement

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■■

Assessment of Postural Discomfort During Power Tiller Operation

by
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Abstract

Subjective self reported estimates of effort expenditure might be quantified using rating of perceived exertion. The discomfort experienced by the subjects was quantified in terms of over all discomfort rating (ODR) and body part discomfort score (BPDS) using rating scales. For the assessment of overall discomfort rating a 10 - point psychophysical rating scale (0 - no discomfort, 10 - extreme discomfort) was used, which is an adoption of the Corlett and Bishop (1976) technique. To measure localized discomfort (BPDS) the Corlett and Bishop (1976) technique was used. Assessments were made at different forward speeds, viz., 1.5 km/h, 1.8 km/h, 2.1 km/h and 2.4 km/h during field trials and 3.5 km/h, 4.0 km/h, 4.5 km/h and 5.0 km/h during transport mode of two power tillers. One was a walking type (7.46 kW) and the other a riding type (8.95 kW). The overall discomfort score and body part discomfort score were increased with increase in forward speed for all operations. The overall discomfort rating (ODR) scale varied from "moderate discomfort" to "more than moderate discomfort" for the walking type power tiller whereas it was scaled as "more than light discomfort" to "moderate discomfort" for the riding type during rototilling. In general, the overall discomfort scores during transport were scaled as "light discomfort" to "more than light discomfort" with the increase in forward speed from 3.5 to 5.0 km/h on farm roads and bitumen roads for both power tillers. The ODR and BPDS values were lower for the riding type power tiller than the walking type power tiller for the rototilling operation, which is indicative of the fact that the seating arrangement in the riding type power tiller reduced the discomfort due to walking. The majority of discomfort was experienced in the arm, leg, and shoulder region for all the subjects for the walking type power tiller during rototilling, whereas the majority of discomfort was concentrated in the lower back, buttocks, thigh and thigh region for the riding type power tiller. The results were indicative of the fact that the analysis of the body part discomfort score during the actual operating conditions can provide information regarding the functional component of the power tiller that could be modified. It was evident that a more ergonomic relationship between operator and machine would permit a less distorted posture and presumably less discomfort.

Introduction

The ergonomic aspects of power tillers are of great importance since working with a power tiller involves considerable physical strain to the operator. Controlling the power tiller while turning causes considerable fatigue to the operator. An operator has to walk behind the machine for a distance of about 15 to 20 km, merely to rototill a hectare of land once. The problem is aggravated when walking behind the machine in puddled soil during the rotopuddling operation in rice fields (Mehta et al., 1997). Humans are able to perceive the strain generated in the body by a given work task and to make absolute and relative judgments about this perceived effort. Thus, one can assess and judge the relationships between the physical stimulus (the work performed) and its perceived sensation and provide a means of assessing the heaviness of a task. Alternatively, it is possible to assess an individual's capability to perform stressful work. Discomfort is the body pain arising as a result of the working posture and or the excessive stress on muscles due to the effort involved in the activity. Sometimes, it is also called overall discomfort or simply discomfort. In many situations, though the work may be well within the physiological limits, the body discomfort may restrict the duration of work. In this paper the discomfort experienced by the power tiller operator was quantified using rating scales during different operations.

Review of Literature

Corlett and Bishop (1976) used body mapping for assessment of postural discomfort at work. The subject's body was divided into 27 regions and the subject was asked to indicate the regions, which were most painful. The subject was also asked to assess total discomfort from the worst on a particular body part, using a five or seven point scale. The scales were graded from ‘no discomfort’ to ‘maximal discomfort’. Legg and Mahanty (1985) compared five modes of carrying a load close to the trunk. In this study the subject was asked if he suffered any discomfort. If it so, he was asked to describe its location by indicating a region of body on a diagram similar to that described by Corlett and Bishop (1976) and to describe the extend of discomfort by giving a rating between 1 and 10, where 1 represented ‘no discomfort’ and 10 represented ‘maximal discomfort’. Fairley (1995) used a general comfort rating that consisted of a 16 cm horizontal line that is marked ‘little discomfort’ at one end and ‘much discomfort’ at the other end. Tiwari and Gite (2000) reported that overall discomfort ratings on a 10-point visual analogue discomfort scale varied from 1.0 to 3.5 for a power tiller with seating attachment and from 2.0 to 5.0 for a power tiller without seating attachment for an operating duration of 20 minutes.

Materials and Methods

Three human subjects were selected for the investigation based on age, weight and physical fitness (Grandjean, 1982 and McArdle et al., 1994). All the subjects were well acquainted with the controls of the power tiller and had experience for different operations. Among different makes of power tillers popular with the farmers of the study region, two power tillers were selected; one walking type (7.46 kW) (Power tiller A) and one riding type (8.95 kW) (Power tiller B). The power tiller was put in proper test condition before conducting the trails. It was in full working order with full fuel tank and radiator, without optional front weights and any specialized components. Tyres used for the tests were of standard size with depth of treads not less than 70 percent of depth of a new tread.

The trials were conducted at the selected four levels of forward speeds, viz., 1.5 km/h, 1.8 km/h, 2.1 km/h and 2.4 km/h during rototilling in untilled and tilled fields and 3.5 km/h, 4.0 km/h, 4.5 km/h and 5.0 km/h during transport with an empty trailer on farm roads and bitumen roads for both power tillers. The surface condition of the untilled field was dry and undulating with a weed intensity of 370 g/m^2. The surface condition of the tilled field was dry with small undulations and without weeds. The soil was sandy clay with a soil moisture and bulk density of 11 percent (d.w.) and 1.31 g/cm^3 for untilled and 7 percent (d.w.) and 1.2 g/cm^3 for tilled condition, respectively. The recommended tyre pressure of 1.5 kg/cm^2 was maintained. Depth of operation was about 15 cm. The surface condition of the farm road was dry, with small undulations and without weeds. The surface condition of the bitumen road was dry and level with medium surface finish without humps. The recommended tyre pressure of 2.5 kg/cm^2 was maintained for the wheels during transport. The mean dry bulb temperature, wet bulb temperature and relative humidity var-

Fig. 1 Visual analoque discomfort scale for assessment of overall body discomfort

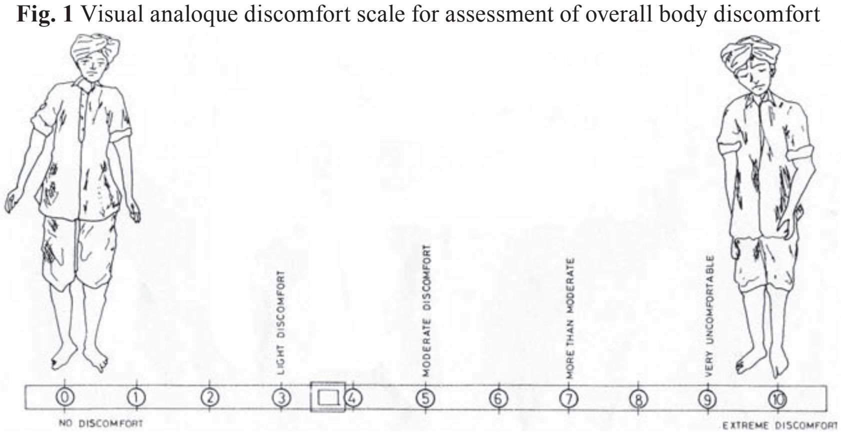
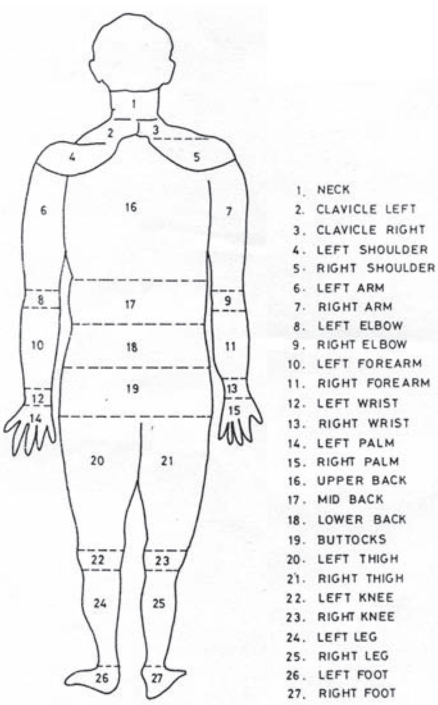


Fig. 2 Regions for evaulating body part discomform score



ied between 25 to 32 ºC, 18 to 25 ºC and 25 to 76 percent, respectively, during the period of evaluation.

The experiment was conducted at different time intervals of the day between 8:30 AM and 5:00 PM. To minimize the effects of variation in environmental and soil factors, the treatments were given in randomized order. The subjects were given information about the experimental requirements so as to enlist their full cooperation. They were asked to report at the work site at 8:00 AM and have a rest for 30 minutes before starting the trial. After 30 minutes of resting, the subject was asked to operate the power tiller for a duration of two hours. The engine was already started by another person with the throttle position set for the required speed and the gearshift lever set in the required position for the selected forward speed. Sufficient rest period was given between the two trials on the same day, with the same subject. The same procedure was repeated three times for all the selected subjects. Assessment of postural discomfort included overall discomfort rating (ODR) and body part discomfort score (BPDS).

i. Overall Discomfort Rating (ODR)

For the assessment of ODR a 10 - point psychophysical rating scale (0 - no discomfort, 10 - extreme discomfort) was used, which is an adoption of Corlett and Bishop (1976) technique. A scale of 70 cm length was fabricated having 0 to 10 digits marked on it equidistantly (**Fig. 1**). A movable pointer was provided to indicate the rating. At the ends of each trial subjects were asked to indicate their overall discomfort rating on the scale. The overall discomfort ratings given by each of the three subjects were averaged to get the mean rating.

ii. Body Part Discomfort Score (BPDS)

The Corlett and Bishop (1976) technique was used to measure localized discomfort. In this technique the subject's body is divided into 27 regions as shown in **Fig. 2**. A body mapping similar to that of **Fig. 2** was made with thermocoal to have a real and meaningful rating of the perceived exertion of the subject. The subject was asked to mention all body parts with discomfort, starting with the worst and the second worst and so on until all parts have been mentioned. The subject was asked to fix the pin on the body part in the order of one pin for maximum pain, two pins for next maximum pain and so on. The number of different groups of body parts which are identified from extreme discomfort to no discomfort represented the number of intensity levels of pain experienced. Each separately reported group can be seen as being separated by a recognizable difference in the level of discomfort. The maximum number of intensity levels of pain experienced for power tiller operations under different terrain conditions was 6 categories. The rating was assigned to these categories in an arithmetic order, viz., first category (body parts experiencing

Table 1 Overall discomfort rating of subjects during rototilling

Terrain	Forward speed, km/h	Power tiller A		Power tiller B	
		Mean value of ODR	Scale	Mean value of ODR	Scale
Untilled	1.5	4.6	Moderate discomfort	4.0	More than light discomfort
	1.8	5.0	Moderate discomfort	4.3	Moderate discomfort
	2.1	5.3	More than moderate discomfort	4.5	Moderate discomfort
	2.4	7.0	More than moderate discomfort	5.2	More than moderate discomfort
Tilled	1.5	4.5	Moderate discomfort	3.8	More than light discomfort
	1.8	4.6	Moderate discomfort	4.0	More than light discomfort
	2.1	5.0	Moderate discomfort	4.3	Moderate discomfort
	2.4	5.3	More than moderate discomfort	5.0	Moderate discomfort

Table 2 Overall discomfort rating of subjects during transport

Terrain	Forward speed, km/h	Power tiller A		Power tiller B	
		Mean value of ODR	Scale	Mean value of ODR	Scale
Farm road	3.0	2.6	Light discomfort	3.2	More than light discomfort
	4.0	2.8	Light discomfort	3.3	More than light discomfort
	4.5	3.2	More than light discomfort	3.8	More than light discomfort
	5.0	3.7	More than light discomfort	4.0	More than light discomfort
Bitumen road	3.5	2.6	Light discomfort	2.8	Light discomfort
	4.0	2.8	Light discomfort	3.0	Light discomfort
	4.5	3.0	Light discomfort	3.2	More than light discomfort
	5.0	3.3	More than light discomfort	3.3	More than light discomfort

maximum pain) rating was allotted as 6 and for second category (body parts experiencing next maximum pain) rating was allotted as 5 and so on. For the sixth category (body parts experiencing least pain) rating was allotted as 1. The number of intensity levels of pain experienced by different subjects might vary. The body part discomfort score of each subject was the rating multiplied by the number of body parts corresponding to each category. The total body part score for a subject was the sum of all individual scores of the body parts assigned by the subject. The body discomfort score of all the subjects was averaged to get the mean score.

Table 4 Body part discomfort score of the subjects for selected operations

Forward speed, km/h	Body part discomfort score (BPDS), mean value	
	Power tiller A	Power tiller B
a. Rototilling in untilled field		
1.5	29.20	24.16
1.8	29.50	24.30
2.1	30.00	27.80
2.4	33.90	29.36
b. Rototilling in tilled field		
1.5	28.33	23.33
1.8	29.16	24.10
2.1	29.80	26.00
2.4	30.66	27.60
c. Transport on farm road		
1.5	21.80	22.50
1.8	22.23	24.03
2.1	24.03	24.53
2.4	24.20	25.16
d. Transport on bitumen road		
1.5	19.16	21.30
1.8	21.67	22.50
2.1	21.80	23.33
2.4	22.23	24.53

Statistical Analysis

The results were statistically analysed using analysis of variance technique (ANOVA) with IRRISTAT package by following Completely Randomized Design (CRD) to assess the effect of levels of variables namely power tiller (P), subject (S), operation (T) and forward speed (F) separately for rototilling and transporting operations for ODR and BPDS.

Results and discussion

i. Overall Discomfort Rating (ODR)

The mean value of overall discomfort scores during rototilling of power tillers A and B in untilled and tilled fields for selected levels of forward speed are furnished in **Table 1**. Overall discomfort rating varied from 4.6 to 7.0 and scaled as "moderate discomfort" to "more than moderate discomfort" during rototilling in untilled field for power tiller A. But for power tiller B, ODR values varying from 4.0 to 5.2 and observed as "more than light discomfort" to "more than moderate discomfort" with the increase in forward speed. The ODR values in tilled field condition were lower than that observed in untilled condition.

The overall discomfort scores during transport (**Table 2**) was scaled as "light discomfort" to "more than light discomfort" with the increase in forward speed from 3.5 to 5.0 km/h on farm roads and bitumen roads for power tiller A. For power tiller B, ODR varied from 3.2 to 4.0 and graded as "more than light discomfort" for all selected levels of forward speed in farm roads. For bitumen roads it was observed as "light discomfort" for selected speeds of 3.5 and 4.0 km/h and exceeded to "more than light discomfort" at higher speeds.

In general, the ODR values were lower for the riding type power tiller (power tiller B) than for the walking type power tiller (power tiller A) for rototilling operation. The provision of seating arrangement on the power tiller reduced the discomfort and hence the rating values were lower. In the transporting operation, power tiller B showed higher values of ODR even though both power tillers were attached with same trailer and seat. This might be due to the difficulty experienced by the subjects in maneuvering and handling of the power tiller B due because power tiller B was heavier than power tiller A. The higher values of ODR in farm roads as compared to bitumen roads suggested that the ODR was influenced by the terrain conditions.

Statistical Analysis

The ANOVA for ODR is furnished in **Table 3**. The 'F' value was significant at the one per cent level of probability for all the treatments. There was significant difference among all the treatments. This was a clear evidence to substantiate the type of power tiller (with and without seat), subjects, terrain condition (untilled and tilled) and the forward speed of operation on the performance of subjects in terms of ODR values. In the treatment effect, the order of significance was highest for

Table 3 Analysis of variance for ODR

SV	DF	SS		MS		F	
		Rototill	Transport	Rototill	Transport	Rototill	Transport
Treatments	47	129.566	47.694	2.757	1.015	11.10**	4.06*
Power tiller (P)	1	16.201	4.375	16.201	4.375	65.26**	17.51**
Subject (S)	2	29.927	11.063	14.963	5.531	60.27**	22.14**
Operation (T)	1	6.125	1.89	6.125	1.89	24.67**	7.57**
Forward speed (F)	3	49.744	15.523	16.581	5.174	66.79**	20.72**

cv = 10.0 %, ** = Significant at 1 % level, * = Significant at 5 % level subject followed by forward speed, power tiller and operation.

ii. Body Part Discomfort Score (BPDS)

The mean values of BPDS of the selected three subjects for selected operations are furnished in **Table 4**. The discomfort score increased for all the operations at all levels of forward speed. For power tiller A during rototilling in field operation, the majority of discomfort was experienced in the left arm, right arm, left leg, right leg and shoulder region for all the subjects. This was because power tiller A was a walking type tractor and the operator had to walk behind the power tiller for the entire period of work. For power tiller B, the majority of discomfort was concentrated in the lower back, buttocks, left thigh and right thigh region since the subject was riding the power tiller. The level of pain was experienced more in the untilled field than in the tilled field. The higher values of BPDS observed in the untilled field condition for the power tiller was indicative of the fact that the terrain condition contributed discomfort to the body regions. The BPDS of the subjects during rototilling in power tiller B was lower than power tiller A for both untilled and tilled fields. This further confirmed earlier results that the seating attachment eliminated the drudgery of walking behind the power tiller.

In transport mode, power tillers A and B showed a major discomfort in the region of buttocks, lower back and thighs as reported by the subjects. The subjects experienced more discomfort on farm roads due to the unevenness and surface undulations on farm roads compared to bitumen roads (medium surface finish). The BPDS of subjects was marginally higher for power tiller B than power tiller A on farm roads and bitumen roads.

Statistical Analysis

The ANOVA for BPDS is furnished in **Table 5**. The 'F' value was significant at 1 percent level of probability for all the treatments. Among the treatments subject was most significant, which indicated the importance of the fitness and ability of the subjects in ergonomic evaluation of equipment. In the treatment effect, the order of significant of power tiller was immediately after the subject, which indicated the effect of type and make of the power tiller on the discomfort experienced by the operators during operation.

Conclusions

Based on the analysis of results, the following conclusions were drawn.

- In general, the overall discomfort rating scale varied from "moderate discomfort" to "more than moderate discomfort" during rototilling, whereas it was scaled as "light discomfort" to "more than light discomfort" during transport mode. The overall discomfort rating (ODR) and body part discomfort score (BPDS) were increased with increase in forward speed for all operations.
- In field operations, overall discomfort rating and body part discomfort score of the subjects for the riding type power tiller (8.95 kW) was lower than the walking type power tiller (7.46 kW).
- In transport, overall discomfort rating and body part discomfort score of the subjects for the riding type power tiller (8.95 kW) was higher than the walking type power tiller (7.46 kW).
- The intensity of pain experienced by the subjects was more in the untilled field than in the tilled field during rototilling and more in farm roads than in bitumen roads during transport.
- The majority of discomfort was experienced in the left arm, right arm, left leg, right leg and shoulder region for all the subjects for the walking type power tiller (7.46 kW) during rototilling, whereas the majority of discomfort was concentrated in the lower back, buttocks, left thigh and right thigh region for riding type power tiller (8.95 kW).
- Pain or discomfort reported in various parts of the body was functionally related to the characteristics of the power tiller and type of operation. This was clearly reflected by the fact that the seating attachment provided in the riding type power tiller eliminated the drudgery due to walking behind the power tiller.
- Among the treatments, subject was most significant which indicated the importance of the

(continued on page23)

Table 5 Analysis of variance for BPDS

SV	DF	SS		MS		F	
		Rototill	Transport	Rototill	Transport	Rototill	Transport
Treatments	47	4,013.04	2,364.5	85.384	50.308	109.74**	185.75**
Power tiller (P)	1	664.78	47.26	664.780	47.265	854.41**	174.52**
Subject (S)	2	2,997.02	2,251.8	1,498.51	1,125.9	1,925.97**	4,157.13**
Operation (T)	1	124.69	17.02	124.694	17.015	160.26**	62.83**
Forward speed (F)	3	157.96	45.75	52.655	15.251	67.68**	56.31**

** = Significant at 1 % level

Agricultural Accidents - A Case Study in Etawah Districts of Uttar Pradesh in India

by

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Abstract

Farm mechanization along with increased application of other agricultural inputs has increased the production and productivity of Indian farms. But, it has also increased casualties through agricultural accidents. Very little information is available about the type and nature of agricultural accidents. Agriculture machinery accident data were collected for the period 1996-2000 for the Etawah district of Uttar Pradesh in India and this data were generalized to the whole district according to the survey. The estimated number of victims was 634 in 2000. Out of the total, 55 of the accidents were fatal and the remaining 579 were non-fatal. The agricultural accident incidence rate per 1000 workers per year in the Etawah district was 0.78. The hand tool-related accidents were insignificant as compared to farm machinery accidents. Major causes of agricultural accidents were human factor, 43.3 %, and machine factor, 20.8 %.

Introduction

In India, about 223 million workers (De et al., 2000) are engaged in agricultural and allied activities. Traditional agriculture utilized mainly human and animal power sources. However, electro-mechanical sources of power are beginning to be extensively used for various farm operations. The agricultural machinery population in the country is estimated at about 160 million and the number of tractors has crossed the 2.75 million mark. Farm mechanization has increased the production and productivity of Indian farms and it has also increased casualties through agricultural accidents. Loss of human life brings sorrow to the victim's family and to the society in addition to causing considerable financial loss to the country as a whole. Because of non-availability of nation wide compiled information on agricultural accidents and lack of adequate and reliable data on etiology of farm accidents, it becomes difficult to quantify the economic burden of these accidents and to identify ways and means of minimizing them. To develop safer equipment and to take corrective measures for minimizing accidents, availability of realistic data on agricultural accidents is most desirable.

Materials and Methods

Agricultural machinery-accident data were collected for the period of 1996-2000 for the Etawah district of Uttar Pradesh, India. The study was done during the month of March to May 2001. Out of eight blocks six blocks were selected for the survey that had maximum tractor density. In the selected blocks a village that had extensive use of farm machinery was selected for the survey. After that, contacts were established with key informants through the advice of the College of Agricultural Engineering and Technology such as Gram Pradhan, Block Development Committee (BDC) member, village level medical practitioners and groups of the farmers in the selected villages.

All twenty-two villages were visited and, with the help of key informants, information on agricultural accidents and related aspects were collected. Farmers of the selected villages were requested to provide the necessary information about the agricultural accidents without any fear of legal implications. They were involved in participatory mode. We were told that the information would only be used for making necessary design modifications in the machines or for making guidelines for safe operation of various agricultural equipment. The preliminary information on agricultural accidents was collected during group meetings and discussion with villagers, at each village. After this, each accident-victimized farmer was contacted for collecting detailed information as per objective. The surveyed data were used to estimate the total agricultural accidents in Etawah district of Uttar Pradesh

Results and Discussion

The total agricultural accidents reported in surveyed villages of different blocks during the period of 1996-2000 was 106. Out of 106, 57 accidents were due to farm machinery, followed by hand tools (43) and others (6). **Table 1** represents the accident-incidence rate. The accident-incidence rate of farm machinery was 2.28 per 1000 machines per year followed by hand tools (0.175 per 1000 workers per year) and others (0.044). However, the total agricultural accident-incidence rate was 0.75 per thousand workers per year in Etawah district of Uttar Pradesh. These data showed hand tool related accidents were insignificant as compared to farm machinery accidents.

Table 2 represents source wise classification of agricultural accidents in surveyed villages. Chaff-cutter accidents were highest, which constituted 20.75 % of the total accidents followed by serrated sickle (15.09 %), thresher (11.30 %), tractors, khurpi and plan edge sickle (each 9.43 %) and disc harrow (2.83 %), sugar cane crushers, potato planter, snake bites and slipping in the field (1.89 % each), electric motors and pump sets, levelers, cultivators, kudali, dog biting and fall from trees (0.94 % each). Machine wise accident-incidence rates were calculated on the basis of total number of each type of machine in all the villages. Highest and lowest accident-incidence rate per 1000 machines per year was for potato planters (50.00) and kudali (0.09) respectively. Due to better design of thresher chute, the accidents by the thresher were less than a few years ago.

Accident Estimation for Each of the Above Categories
(a) Farm Machinery

This category includes accidents caused due to agricultural machinery, excluding hand tools. To estimate the number of farm machinery related accidents, the accident-incidence rate was calculated from the total number of reported farm machinery-related accidents and total number of accident-prone agricultural machines in twenty two villages. The accidents-incidence rate was multiplied by the total number of accident-prone agricultural machines in the surveyed district during the year 2000 for calculating the total number of farm machinery related accidents.

The estimation of the total agricultural machinery population in Etawah district during the year 2000 was 160500.

- Number of machinery-related accidents in 22 surveyed villages per year = 57/5 = 11.4
- Number of machinery-related fatal accidents per year in surveyed villages = 6/5 = 1.2
- Number of machinery-related

Table 1 Total agricultural accidents in surveyed villages and incidence rate

Type of source	No. of accidents	Incidence rate
Farm machinery	57	2.28*
Hand tools	43	0.175**
Others	6	0.044***
Total	106	0.75****

*Number of victims/1000 machines/year, **Number of victims/1000 hand tools/year, ***Number of victims/1000 workers/years, ****Number of victims/1000 workers/year

Table 2 Source wise classification of agricultural accidents in surveyed villages

Sources of agricultural accidents	Total no. of victims	Total no. of machines	Incidence rate/1000/year
A. Accident prone agricultural machiney			
Tractor	10 (9.43)*	119	16.81
Thresher	12 (11.30)	129	18.60
Chaff cutter	22 (20.75)	2,228	1.97
Electric motors and pump sets	1 (0.94)	75	2.67
Diesel engine and pump sets	3 (2.83)	520	1.15
Sugar cane crusher	2 (1.89)	60	6.67
Leveler	1 (0.94)	10	20.00
Cultivators	1 (0.94)	112	1.79
Disc harrow	3 (2.83)	112	5.36
Potato planter	2 (1.89)	8	50.00
B. Hand tools			
Serrated sickle	16 (15.09)	14,766	0.22
Plain edge sickle	10 (9.43)	9,820	0.20
Spade	5 (4.72)	3,925	0.25
Kudali	1 (0.94)	2,180	0.09
Khurpi	10 (9.43)	9,850	0.20
Chopper knife	1 (0.94)	1,850	0.11
C. Others			
Snake bite	2 (1.89)	-	-
Dog biting	1 (0.94)	-	-
Slipping in the field	2 (1.89)	-	-
Fall from trees	1 (0.94)	-	-
Total	106 (100)		

*Figures in parentheses represents % of total accidents

non-fatal accidents in surveyed villages per year = 5 1/5 = 10.2
- Total number of accidents-prone agricultural machines in 22 villages = 5001
- Accident-incidence rate per 1000 machines per year = (11.4/5001) x 1000 =2.28
- Incidence rate of fatal accidents per 1000 machines per year = (1.2/5001) x 1000 = 0.24
- Incidence rate of non-fatal accidents per 1000 machines per year = (10.2/5001) x 1000 = 2.04
- Estimated number of accident-prone agricultural machines in Etawah district for the year 2000 = 160500
- Estimated number of machinery-related accidents per year in Etawah district = (2.28 x 160500)/1000 ≈ 366
- Estimated number of machinery-related fatal accidents per year in Etawah district = (0.24 x 160500)/1000 ≈ 39
- Estimated number of machinery-related non-fatal accidents per year in Etawah district = (2.04 x 160500)/1000 ≈ 327

(b) Hand Tools

This category includes accidents caused due to agricultural hand tools such as serrated sickle, khurpi and chopping knife (gandasa). To estimate the number of hand tool-related accidents, the incidence rate was calculated from the total number of reported accidents due to hand tools and total number of these tools in 22 surveyed villages of the Etawah district. For calculation of total hand tool accidents, the incidence rate was multiplied by the total number of agricultural hand tools in the surveyed district. The population of hand tools in the Etawah district was estimated by multiplying the number of hand tools per worker in the surveyed villages by the total number of agricultural workers in the Etawah district. The population of hand tools in the surveyed district was estimated by multiplying the number of hand tools per worker in the surveyed villages by the total number of agricultural workers in the Etawah district.

- Number of hand tool-related accidents in 22 surveyed villages per year = 43/5 = 8.6
- Total number of hand tools in 22 villages = 49220
- Total number of agricultural workers in 22 villages = 27126
- Number or hand tools per worker in surveyed villages = 49220/27126 = 1.81
- Estimated population of agricultural workers in Etawah district for the year 2000 (**Table 2**) = 745160
- Estimated number of hand tools in Etawah district for the year 2000 =1.81 x 745160 = 1348740
- Accident-incidence rate per 1000 hand tools per year = (8.6/49220) x 1000 = 0.175
- Estimated number of hand tools related accidents per year in Etawah district = (0.175 x 1348740)/1000 = 236

All these accidents are of non-fatal nature.

(c) Other

This category includes accidents such as to snakebites, electrocution due to lighting, slip in the field and fall from trees. To estimate the number of accidents of this category, the accident incidence rate per 1000 workers per year was calculated from the total number of reported accidents under this category in twenty-two villages and total number of agricultural workers in these villages. This accident-incidence rate was multiplied by the total number of agricultural workers in the Etawah district during the year 2000 to get the total estimated number of accidents under this category.

- Number of other related acci-

Table 3 Estimated number of agricultural accidents for year 2000

Type of source	Fatal	Non-fatal	Total
Farm machinery	39	327	366
Hand tools	-	236	236
Others	16	16	32
Total	55	579	634

Fig. 2 Total agricultural accidents in year 2000

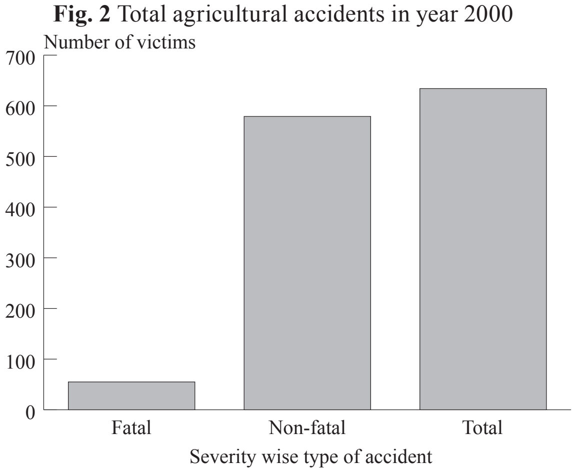


Fig. 1 Source wise accidents in surveyed villages

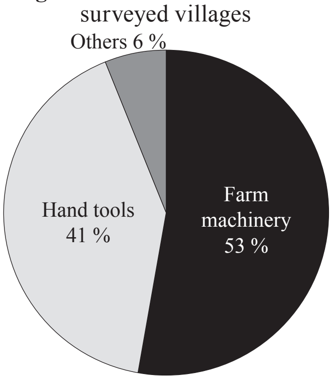
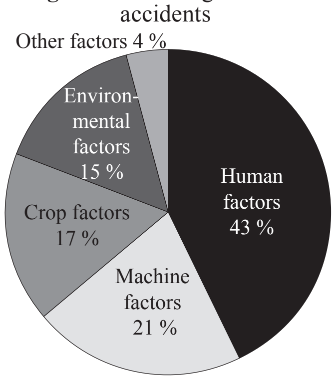


Fig. 3 Couses of agricultural accidents



dents in 22 surveyed villages per year = 6/5 = 1.2
- Number of fatal accidents per year in surveyed villages = 3/5 = 0.6
- Number of non-fatal accidents in surveyed villages per year = 6/5 = 0.6
- Total number of agricultural workers in 22 villages = 27125
- Accident-incidence rate per 1000 workers per year = (1.2/27125) x1000 =0.044
- Incidence rate of fatal accidents per 1000 workers per year = (0.6/27125) x 1000 = 0.022
- Incidence rate of non-fatal accidents per 1000 workers per year = (0.6/27125) x 1000 = 0.022
- Estimated population of agricultural workers in Etawah district for the year 2000 (**Table 2**) = 745160
- Estimated number of other agricultural accidents per year in Etawah district = (0.044 x 745160)/1000 = 32
- Estimated number of fatal accidents under this category per year in Etawah district = (0.022 x 745160)/1000 = 16
- Estimated number of non-fatal accidents under this category per year in Etawah district = (0.022 x 745160)/1000 = 16

Thus the total number of agricultural accidents in Etawah district worked out to be as 634 given in **Table 3** and **Fig. 2**.

Causes of Agricultural Accidents in Surveyed Villages

Causes of agricultural accidents were given in **Table 4** and **Fig. 3**. The highest percentage of agricultural accidents was due to human factor (43.30 %) followed by machine factor (20.80 %), crop factor (16.93 %), environment factor (15.20 %) and other (3.77 %). For the human factor, the highest agricultural accidents were due to no inexperienced machine operators (11.8 %) and lowest due to physical incapabilities (2.3 %). In the machine factor, the highest number of accidents was due to failure of a machine component and lowest due to higher speed of operation of machines. In the crop factor, accidents were due to wet crop (12.9 %) and foreign material (4.0%). In the environmental factor, the highest number of accidents was due to improper pathway (7.9 %) and lowest due to more noise and dusty environment (2.8 %). In other factor, the highest number of accidents was due to snake bites (1.89 %) and lowest due to dog biting and falling from a tree (0.94 %).

Table 4 Causes of agricultural accidents in surveyed village

Factors involved in agricultural accident	Percent, %	No./1000 agricultural worker in 5 years
A. Human factors		
No experience of use	11.8	0.46
Non use of protective dress and device	8.9	0.35
Loose garments	7.4	0.29
Un awareness	5.2	0.20
Lack of proper training	4.8	0.19
Use of intoxicant	2.9	0.11
Physical in capabilities	2.3	0.09
Total	43.3	1.69
B. Machine factors		
Failure of component	6.2	0.24
To much vibration of component	5.9	0.23
Poor quality of machine	4.3	0.17
Poor maintenance	2.5	0.10
Higher speed	1.9	0.07
Total	20.8	0.81
C. Crop factors		
Wet crop of threshing and cutting	12.9	0.50
Foreign material involved in crop	4.03	0.16
Total	16.93	0.66
D. Environmental factors		
Improper path way	7.9	0.31
Poor light	4.5	0.18
More noise and dusty environment	2.8	0.11
Total	15.2	0.60
E. Other facors		
Snake bites	1.89	0.07
Dog biting	0.94	0.04
Fall down from the trees	0.94	0.04
Total	3.77	0.15
Grand total	100.00	3.91

Suggested Strategies for Minimizing the Agricultural Accidents

1. Provision of Roll Over Protective Structure (ROPS) on the tractor can help to reduce the death caused in tractor accidents due to crushing of operator in over turning accidents.
2. Provision of turning indicators and rear lights should be made mandatory on tractor-trailers.
3. Design modifications in tractors and other farm equipment are needed for easy and safe hitching of the equipment with the tractors.
4. It is necessary to develop an ergonomically layout for tractor operators work place.
5. Always, do not permit children to sit on the trailer.
6. Always, avoid taking sharp

turns with the tractor.

7. Driver should be a skilled person with knowledge of tractors and farm machines.
8. Driver should be required to drive the tractor under controlled speed.
9. Threshers should have safe feeding chutes or other safe feeding devices as specified in BIS standard.
10. The chaff cutters should have built in safe feeding devices.
11. The chaff cutters should have locking system to avoid children accidents.
12. The rotating parts of various prime movers and farm equipment should have proper guards.
13. Use of personal protective gadgets like hand gloves and gumboots should be encouraged to prevent accidents due to hand tools and snakebites.
14. As most of the snakebites occur at farms in rural areas, antivenin injections need to be made available at all the primary health centres. It can help in reducing the number of deaths due to snakebites.
15. The installation of pump sets and motors need to be done in proper manner to avoid electrocution accidents.
16. Training courses should be organized for tractor operators at block levels for proper and safe operation of the tractors and tractor-operated equipment.
17. Farmers should always avoid sitting on the tractor drawn levelers or other equipment.

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(Continued from page18)

Assessment of Postural Discomfort During Power Tiller Operation

physical fitness and ability of the subjects in ergonomic evaluation of equipment.

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The Department of Biosystems Engineering (BSE) at Jordan University of Science and Technology

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Abstract

The establishment of the Biosystems Engineering Department (BSE) in the faculty of engineering at Jordan University of Science and Technology is a milestone in keeping up with the fast growing area of Biological engineering that may be simply defined as the engineering of living things. Biosystems engineers use their combined knowledge in biology, physics, and engineering to solve problems in food and in agriculture industry. Thus, biosystems engineers are prepared for operational and design work in firms involved, not only in production, but also in processing of farm products as well as in food production and developing processes for materials of biological nature. One of the major tasks of biosystems engineers is to obtain a sustainable management of the natural biological resources by maintaining a delicate balance between the ever increasing demand on food products and the natural resources while maintaining, at the same time, a healthy environment by the production, manufacturing and utilization of renewable resources in a safe environment.

Introduction

Jordan University of Science and Technology (JUST) is one of the largest state universities in Jordan consisting of 11 faculties, 50 departments and many research institutes and facilities. The university has provided higher education to thousands of students over the period of less than twenty years of its existence. The main campus of the university covers an area of 12 km^2, and its buildings have a total floor space of 350,000 square meters. The teaching and administrative staff numbers around 2,500 with about 700 faculty members. The number of students enrolled in the university exceeds 15,000 students from 41 nationalities. The education at the undergraduate level is given in 41 major disciplines; and the graduate education is given in 72 fields of study. The university is well known for its blend of academic and practical excellence embracing future-oriented and progressive features. There are eleven faculties namely: Faculty of Engineering, Faculty of Computer and Information Technology, Faculty of Medicine, Faculty of Dentistry, Faculty of Pharmacy, Faculty of Nursing, Faculty of Science and Arts, Faculty of Agriculture, Faculty of Veterinary Medicine, Faculty of Applied Science, Faculty of Graduate Studies, Deanship of Research and Deanship of Student Affairs. The university was established in 1987 as a frontier research and educational center in the north of Jordan. The main campus is located at Irbid city, 70 kilometers north of the capital, Amman.

Department of Biosystems Engineering (BSE)

The Department of Biosystems Engineering was established in 2001 as a successor of the Agricultural Engineering and Technology Department which was established earlier in 1991 (Nidal and Khdair 2000). The distinctive feature in this department was to create sustainable technologies by applying biosciences. The department utilizes the wonderfulness and strangeness of living things and applies their elaborate mechanisms to practical technologies and offers three specializations, consisting of the following:

1. Field Power and Machinery Engineering: Power and Machinery engineers have transformed from a manual to a mechanized profession, but, still, their task is not complete due to the renewed interest in environment, laboratory safety, and energy consumption. Field Power and Machinery make a significant part of the food production chain. Engineers in this option design, develop, and test the different types of traction machinery in addition to assisting the developments of mechanisms for food handling. Furthermore, they seek the development of environment-friendly and renewable alternative fuel sources.

2. Irrigation and Bioenvironmental Engineering: This option focuses on the management and preservation of biological resources, especially water and soil, by developing and designing systems for the management of water and water quality, controlling, erosion and contamination of soil, and treatment of biological wastes for the sustainable use of soil and water resources in order to improve the quantity and quality of food production.

3. Food Engineering: The food industry is one of the most important contributors to the world economy. This ever-changing industry must keep up with the changing needs of consumers from a health and environment perspective. Food engineers design and develop methods and processes to treat, package, store, transport and distribute food products, which require sound knowledge in the physical and the microbiological properties of foods. This option involves studying topics such as heat, mass and energy transfer, mechanical and other separation methods, cooling and freezing, drying, packaging and treatment and processing of products to increase their value.

The number of under-graduate students enrolled in the department is around 500. The department has five research laboratories; soil, irrigation, power and machinery, geographic information systems and food technology lab. The department advocates "education by practical and hands-on training" in addition to theory.

During the first three years all students in the program take common courses and choose one of the three options available at the department to continue the fourth and the fifth years. Currently there are twelve faculty members in the department who have received their PhD degrees from the top ten universities in the United States and Canada. The faculty distribution according to their specialization is as follows: six in irrigation and environment, four in field power and machinery and two in food engineering.

The Department Curricula

One school year is divided into three semesters: fall, spring and summer. The fall and spring semester last for 16 weeks each, while summer semester lasts for 8 weeks. The students attend lectures, take part in seminars, laboratory and workshop activities. The maximum number of students taking part in laboratory and seminars is 15 to make teaching and instruction more efficient and practical. The number of credit hours required for graduation from the department is 159 credit hours. These credit hours are distributed to three categories; university requirements 25 credit hours, college requirements 29 credit hours; and department requirements 105 credit hours, as shown in (**Table 1**).

Table 1 Categories of the biosystems engineering program

Categories	Credit hours
University requirements (Languege, education and humanties; Computer literacy)	25
College requirements (Mathematics, physics, chemistry and their laboratories)	29
Department requires (Quantum mechanics, strength of material, engineering drawning, crop and soil science; Food engineering, fluid machinery and hydraulics; Thermodynamics, heat transfer, field machinery, engineering economy, machine design, irrigation engineering, biological solid waste and engineering training)	105
Total	159

The curriculum is divided into two stages. The first stage, covering three years, is made up of general study. Most of the subjects are compulsory. During the first three years, students are given a solid and strong background in basic sciences (Mathematics, Physics, Chemistry, Biology and Computer Programming) as well as fundamentals in Engineering (**Table 2**). In the second stage of the curricula (fourth and fifth year) students have the opportunity to choose their study program in keeping with regulations set by the department. The students should choose their major from the three optional specializations available at the department namely: Field Power and Machinery; Irrigation and Environmental Engineering; or Food Engineering as shown in (**Table 3**). The students are not limited to subjects of their specialization; they may choose up to 6 credit hours from other specializations. During the summer vacations proceeding the last year of study students have to go through a two month comprehensive practical training in private, cooperative or public agricultural farms or food factories in Jordan or abroad. The study program at the department is completed by a graduate project presentation. The student undertakes an independent project under the supervision of a faculty advisor. The general objective of the graduation project is to improve the student's skills, to develop independence and creativity and to give the experience of problem solving by integrating the principles of Biosystems engineering.

Biosystem engineering has to deal with both life and production planning for the rural community. For example, emphasis may be on improving fields for high productivity and work efficiency, making better use of agricultural machinery, and improving the use of water. Graduates of the farm power and machinery program are expected to be responsible for the following: introduce new designs and concepts of agricultural machinery to perform certain and specific jobs; adjust and improve designs of existing machinery to maximize performance under local conditions; optimize the use of existing farm machinery and advice farmers in selecting appropriate farm equipment for specific operations; combine the use of land, labor, and capital to achieve the highest possible productivity; carry out comparative tests and evaluate the performance of different agricultural machinery and vehicles; match power units to the size and type of the machines to enable all field operations to be carried out on time with minimum cost; and study problems that might arise as a result of the interactions between agricultural machineries with soil. Graduates of the irrigation and environment option are expected to determine the crop needs for water which requires knowledge in evapotranspiration and the factors affecting it; how to preserve water in upper soils to be used by plants; how to construct dams and water structures for storage and conveyance of water to fields; design irrigation networks that ensure efficient distribution of water to plants with least water loss; reclamation of saline soils by designing and construction proper drainage systems to reduce soil salinity; and management of water distribution for agricultural projects to avoid excessive use of water, and track changes in soil and water quality due to application of agrochemical in order to preserve the environment.

The department has the following teaching and research facilities: laboratories of soil and water; irrigation and drainage; geographic information system (GIS); outdoor facilities for irrigation; farm power and machinery lab and food lab. The department also has an experimental plot for the faculty and senior graduate students to conduct their research and for field demonstration. The faculty and students of the department have further access to other facilities and equipment in other departments such as fluid and hydraulic power and surveying laboratories in Civil Engineering Department; and strength of material and internal combustion engine and instrumentation laboratories in the Mechanical Engineering Department.

Shortage of the Previous Program

In Jordan and neighboring countries in the middle east, agronomist are mistakenly named as agricultural engineers who are, in fact, agriculturists and experts in agricultural sciences and not in an agricultural engineering area. Agricultural science and agricultural engineering are two different disciplines that compliment each other. The first graduates from the department suffered from this problem but, with the aid of the faculty in the department, the problem was, subsequently, corrected. The small number of student applicants was a major problem in the department until recently. As mentioned earlier, this came from a mixed understanding of agronomy and agricultural engineering but this problem seems to be vanishing since the number of applicants has reached 120 students for the academic year 2002.

Future Plans and Graduate Program

After the first graduates went into

Table 2 Recommended program of study for the bachelor's degree in biosystems

First semester		Second semester	
Course title	Credit hours	Course title	Credit hours
First year			
Arabic language	3	General physics II	3
English language I	3	General physics lab	1
General physics I	3	General chemistry II	3
General chemistry I	3	General chemistry lab	1
Calculus I	3	Calculus II	3
General biology	3	Arabic language lab	1
		Computers literacy	3
		English language II	3
Total	18	Total	18
Second year			
Crop science	3	Dynamics	3
Static	3	Strength of materials	3
Engineering drawing	3	Food science for engineers	2
Intermediate analysis	3	Ordinary differential equations	3
Programming language (C++)	3	Engineering workshops	2
		Military science	3
Total	15	Total	16
Third year			
Theory of machines	3	Applied hydraulics	3
Strength of materials lab	1	Fluids mechanics and hydraulics lab	1
Fluid mechanics	3	Heat and mass transfer	3
Thermodynamics	3	Geographical information systems GIS, GIS lab	1
Soil science	3	Evapotranspiration	3
Soil lab	1	Properties and mechanics of biomaterials	3
University elective	3		
Total	17	Total	16

the job markets, a feedback from the students was studied thoroughly to determine their performance at various positions. Full evaluation and modification of the program and study plan was made to tailor a new program to meet the needs of changing markets. The graduates find jobs in agricultural food processing enterprises, governmental organization dealing with soil, water and irrigation plants, service and maintenance, supply and sales engineering, technical and economic activities in road and town transport and in environmental protection institutions in Jordan and the Gulf.

As to the graduate program, we have a newly established master's degree. The graduate program leading to the degree of Master of Science, offers advanced courses in both engineering and socio-economic fields of agricultural and biological system design and a seminar on current topics of each field. The master's plan contains two options; thesis track or comprehensive exam track as shown in (**Table 4**). These graduate students will work as teaching and research assistants in the department during their master's study.

Faculty Research Area of Interest

The research conducted by the faculty in the department covers a wide range of research areas that reflect the interdisplenary nature of the biosystem engineering depart-

Table 3 Undergraduate disciplines (fourth and fifth year)

Course	Brief description
Field power and machinery engineering	
Machine Design I, II	Stress Analysis in machine elements, Failure theories, Fatigue. Design of machine elements: bolt, spring, shaft, gear, bearings, clutches and brakes
Stability and Traction of Off- road Vehicles	Traction theory, weight distribution and stability, turns at high speed, hitch and hydraulic control systems, Power transmission system and final drive
Harvesting Machines	Hay and forage harvesting. Handling and Packaging. Combines. Harvesting losses. Root crop harvesting. Fruit and vegetable harvesting
Soil-Machines Relations	Functions, methods, and implements of soil tillage. Analysis of stresses and strains in soil due to machine-applied loads forces causing soil compaction
Power and Machinery Lab	Test of the power and efficiency of engines and tractors; Evaluation of the performance of different field machines and implements.
Internal Combustion Engines	Classification of I.C. engines, engine systems, fuel types, the combustion processes. Ideal cycles and actual and pollution from engine exhaust
Bioenvironmental and irrigation engineering	
Hydrology	Hydrologic cycle, evaporation, transpiration, precipitation, surface runoff, infiltration, Hydrographs, groundwater. Aquifers, Flow toward wells
Irrigation and Drainage Lab	Experimentation on subjects related to irrigation and drainage systems
Water Control Systems	Analysis and design of field systems for water control in Open channels. Design of weirs, flumes, culverts and spillways
Analysis and Design of Structures	Introduction to construction materials, analysis of statically determinate structures, design of concrete members: beams, slabs, columns, footing
Treatment and Reuse of Contaminated Water	Standards and variables of water quality. Physical, chemical and biological treatment of water. Reuse of treated water in agriculture
Soil Conservation and Drainage	Soil and water conservation, runoff and soil erosion by water and air. Analysis and design of surface and subsurface drainage systems, wells
Design of Irrigation Systems	Design of pressurized irrigation systems, trickle and sprinkler irrigation. Design of mainlines and laterals. Types and characteristics of sprinklers
Contaminant Transport in the Environment	Sources of pollution. Mechanisms of contaminant: dispersion; transport flowing, adsorption, mixing; contaminant decay, air pollution
Food engineering	
Food Chemistry Analytical Chemistry	Introduction to food chemistry, Acids and bases, Proteins, Fats, Enzymes, Carbohydrates, Vitamins, Minerals and colors, Food additives, Flavors
Food Processing Systems	Functional processes, machinery used in biosystems engineering including pumping, blowing, conveying, mixing, separation atomization, Power requirements, efficiency and failure modes
Seminar in Food Engineering	Writing technical papers and presentation. Discussion of the role of food engineer in the society
Food Engineering I, II	Introduction to food industry, food microbiology and safety, thermal processing of food freezing & refrigeration, evaporation & drying
Food Chemistry Lab	Practical application in food chemistry
Food Engineering Lab	Practical application of food engineering processes
Post harvest Engineering	Engineering principles involved storage and handling of grains and horticultural crops between harvest and processing.
Food Packaging and Sanitation Eng	Introduction to packaging, labeling and Communication, shelf life prediction and modeling. Cleaners and sanitizers, Sanitation equipment and systems

ment and the special interest of each faculty member. It includes, but is not limited to, the following: machine design and testing, machine soil relationship, tillage systems, crop harvesting machines, pesticide application, waste management, finite element modeling and analysis, green houses and computer simulation.

Irrigation and environment, on the other hand, conducts research related to irrigation and drainage, crop water requirements, evapotranspiration, plant microclimate, hydrological and groundwater modeling, water harvesting and contaminant movement through soils and water bodies, water and wastewater treatment, geographic information systems, remote sensing, precision agriculture, waste management for biological production systems, and water resources management.

The faculty of food engineering conducts research related to development of sensing technology for biological materials using non-destructive techniques by microwaves and radio waves, developing processing, treatment, and separation techniques for agricultural and food waste streams, design of instrumentation for off-road vehicles, development of a mechanical probe for nondestructive apple firmness evaluation, machinery systems for food production and processing, and rheology of biomaterials.

Fig. 1 University canpus

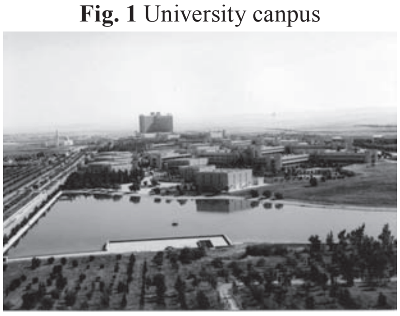

Fig. 2 King abdullah university hospital

Conclusions

The new graduates of the department are expected to make a great contribution to the development and advancement of the agriculture sector in the country and the region. The program will become a popular branch in the college of engineering at the university because of its uniqueness. The department aims to let students acquire a profound knowledge of their specialty during a five-year study so they can contribute to the development sciences in agriculture, biological resources and environmental conservation in public and private research institutions and enterprises to achieve national development and prosperity.

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Table 4 Proposed master program

Duration..	2 years
Degree title..................................	Master of science
Degree requirement..................	25 credits + master thesis 34 credit (non-thesis)

Course (credit)	
A. Compulsory courses: 13 credit	
Experimental design and data analysis	(3)
Advanced irrigation and drainage	(3)
Advanced food engineering	(3)
Advanced field power and machinery	(3)
Seminar in biosystems engineering	(1)
B. Elective courses: 12 credit from the following	
Optimization techniques	(3)
Modeling and simulation in BSE	(3)
Instrumentation and measurement	(3)
Similitude: Theory and applications	(3)
Numerical methods for engineers	(3)
Environmental soil and water chemistry	(3)
Soil physics	(3)
Climatology for biosystems engineers	(3)
Meteorology for biosystems engineers	(3)
Mechanics of non-newtonian fluids	(3)
Hydrologic modeling	(3)
Erosion control	(3)
Soil remediation	(3)
Advanced GIS and GPS in BSE	(3)
Remote sensing	(3)
Environmental control for plants and animals	(3)
Physical principle of the plant biosystem	(3)
Advanced micro irrigation	(3)
Special topics in BSE	(3)

Evaluation, Constraints and Acceptability of Different Types of Vertical Conveyer Reaper for Harvesting Rice in Coastal Orissa, India

by
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Abstract

One vertical conveyer reaper mounted on a tractor and three different makes of self propelled reaper were evaluated for harvesting rice in CRRI farm and nearby farmers' fields in coastal districts of Orissa, India. The average field capacity for the tractor operated reaper was 0.34 ha/h whereas the average field capacity for a self-propelled reaper was 0.19 ha/h. The grain loss was less than 0.5 % and was admissible. The manpower requirement for the reaper was 59-61 h/ha while that for manual harvesting was 240 h/ha. The cost of harvesting was cheaper. However, the predicament of land situation, approach road, and standing water at the time of harvesting stands in the way of acceptability of the machine. However, the availability of the machine and easy and quick availability of spare parts is a must for large scale acceptance of the reaper windrower.

Introduction

Rice is a predominant crop of coastal Orissa in India. It is grown on 4.2 million Ha in Orissa. The topography, soil characteristics, and rainfall pattern enables the field to hold water throughout the growing season. In Orissa, like all other agricultural operations, harvesting is still done manually. There is a shortage of labour and labour is costly at the time of harvesting. Delayed harvesting results in loss of produce due to rodents, storms, unseasonal rains and shattering. Though the combine harvester for rice is indigenously available and efficient, its exorbitant price is not affordable even by well to do farmers. The combine cuts and chops the straw and leaves it in the field. Therefore, the combine is not acceptable at this stage of socio-economic status of rice farmers. Only the vertical conveyer reaper was found to be useful for the work and affordable by a tractor owner or medium size farmer as the rice straw is not damaged by the reaper and is used as animal feed and construction material for rural house roofing.

Review of Literature

Singh et al. (1988) found that, in Pakistan, the time required for harvesting wheat by mechanical reaper was less than 50 % of that of manual method and harvesting losses due to use of the machine (3.3-4.6 % of product) was at par with losses due to manual harvesting. The time required for reaping alone by reaper was 6 % of the time taken for manual cutting of crop by sickle. Yadav et al. (1992) designed a bullock drawn reaper for seed such as wheat and linseed. They claim that the cost of operation is less than manual harvesting and tractor drawn reaper. They also claim that the machine can even be drawn by a pair of small bullocks. Sheruddin Bukhari et al. (1991), in Pakistan, found that the total harvesting losses in wheat due to use of reaper was less than 50 % of the loss by sickle harvesting. They also found that the labour requirement for harvesting by reaper was less than 50 % of sickle harvesting. Devnani et al. (1985) designed a tractor mounted vertical conveyer reaper and power tiller for harvesting wheat and rice. The field capacity for the tractor mounted and power tiller mounted reapers was 0.337 ha/h and 0.269 ha/h, respectively. Cost of harvesting by tractor mounted and power tiller mounted reaper was 20-38 % lower than manual harvesting. The losses were reported to be 4-6 %. However, some of the losses were recoverable type. The labour requirement for machine harvesting was about one third of manual harvesting. Increased field capacity reduced the cost of operation by the reaper. Chauhan et al. (1994) found the adoption behaviour of farmers on tractor operated reapers in Punjab, India. They found that, though the machine harvested the crop at a faster rate, the farmers could not handle the crop at the same pace after harvesting. The height of cut of the crop due to machine reaping was more, thus, problematic for subsequent seedbed preparation. After sales service was poor and the farmers were not getting spare parts in case of break down. The machine could not be operated in the case of lodged crop. Machine harvesting loses much of straw as the crop is cut higher.

Materials and Methods

One tractor mounted reaper manufactured by Sherpur Agro Industries, Punjab, and three different models of self-propelled reapers were used in the test. Out of the self-propelled reaper, one of Swathi make manufactured at Coimbatore, India had a separate gearbox for the reaping unit and the power was transmitted from the engine by V-belt and pulley through the gear box to the reaping unit. The tractor-mounted reaper was attached to the front of the tractor through a 3-point hitch system. The reaper unit could be raised or lowered by the hydraulic system of the tractor connected to the reaper hydraulic unit through a flexible pipe. The raising and lowering of the reaper unit was accurate and could be positioned by a nut and bolt. The power was transmitted from the PTO shaft of the tractor to the drive shaft through a V- belt and pulley. The drive shaft, which was mounted on the tractor on bearings, had a universal joint and hollow splined shaft at one end and a V-pulley at the other. The hollow splined shaft fitted into the solid splined shaft of the gearbox of the reaper unit. Power was taken from the gear box to the cutter bar and the conveying unit by V-belt and pulley. The conveying unit had two flat belts with lugs fitted at equal distances and star wheels and guiding wires to hold back the cut crop from falling down. The whole crop was wind rowed and thrown at the right side of the reaping unit (**Fig. 1**).

The self-propelled unit had all the components similar to the tractor mounted unit. Only the raising and lowering of the machine could be achieved hydraulically in the tractor-mounted machine, where, as in the self-propelled machine, it was done manually by lowering or raising the handle The KAMCO self propelled reaper manufactured by Kerala Agro Machinery Corporation, India was the smoothest and noiseless one. Its power unit was an engine run on kerosene. The power train consisted of belt pulley, chain and gear box properly lubricated wherever necessary. For conveying of the crop, other reapers use flat belts with lugs where as KAMCO reaper used a chain with lugs (**Fig. 2**). It was highly balanced and had smooth operation without noise.

All the four models of reaper were tested in CRRI farm and farmers' field to find their efficency in harvesting rice and farmers' opinion for adoption of the machine. For testing in the farm all the crop parameters were observed and the field capacity, losses and machine parameters were noted. After testing in the farmers' field, the observations and opinions of the farmers were recorded.

Results and Discussions

Performance data were collected to assess the field capacity, field effi-

Fig. 1 Tractor mounted reaper

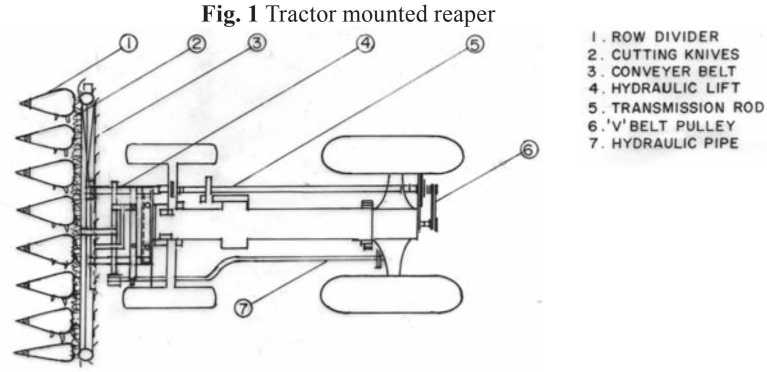
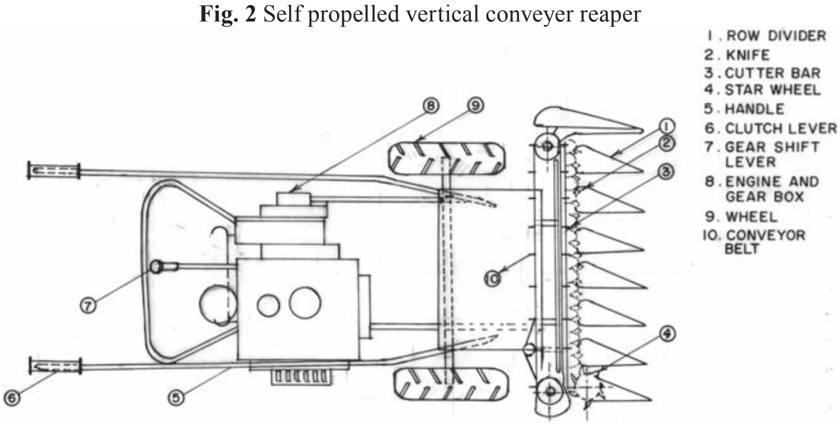


Fig. 2 Self propelled vertical conveyer reaper



ciency, losses due to machine operation, fuel consumption and labour requirement.

Field Capacity

The tractor-mounted reaper was attached to a 35 BHP Massey-Fergussion tractor. The width of cut of the reaper was 180 cm. The average field capacity was 0.34 ha/h. The field efficiency was 69 %. The fuel consumption was 4.1 liters/hour. The synchronization of forward speed of the tractor with cutting speed of reaper was very important for smooth cutting operation, non-clogging of the cut crop and a perfect and neat windrow. The self-propelled walking type reaper had a field capacity of 0.19 ha/h, a cutting width of 1.0 meter and field efficiency of 76 %. The field efficiency of the tractor-mounted reaper was lower because of the frequent turns it had to take at the corner of small fields. The windrow obtained for some models of self-propelled reaper was in a haphazard manner. There was a major mix up of the ear head portion with the root side of the crop.

The KAMCO (Kerala Agro Machinery Corporation) self-propelled walking type reaper gave a field capacity of 0.19 ha/h and a field efficiency of 75 %. The operation was smooth, without noise and vibration and without any exhaustion to the operator. The windrows obtained were neat, without any mix up. The height of cut above ground level for the tractor reaper was more than 10 cm where as the height of cut in case of self propelled reaper was 7-8 cm.

Labour Requirement

The skilled labour required to operate the tractor mounted reaper windrower was 2.94 h/ha. How ever unskilled labour was required to cut the sides and corner of the plot. The unskilled labour was also required to cut or raise the lodged crop, to gather, and bundle the cut crop. The unskilled labour required for the tractor mounted reaper was 56 man- h/ha (**Table 2**). The skilled labour required for the self-propelled reaper was 5.23 man-h/ha and unskilled labour requirement for side cutting, gathering and bundling was 52 man- h/ha. As the walking type reaper was more maneuverable, less unskilled labour was required. Unskilled labour requirement with the KAMCO walking type reaper was less because of the neat windrow obtained. Inequality in the requirement of labour was due to the variation in field size, length to breadth ratio and crop and soil conditions at the time of harvesting.

Table 1 Cost of reaping by different reapers

Item	Tractor	Tractor mounted reaper	Self propelled reaper
Purchase cost, $	6,522	1,087	1,196
Useful life, years	10	5	5
Yearly use, hours	1,300	300	300
Salvage value, $	652	109	120
Fixed cost, $/hr			
Depreciation, $	0.45	0.65	0.72
Interest $ (10 % on average investment)	0.28	0.20	0.22
Taxes, insurance, shelter $ (2.5 % on initial investment)	0.13	0.09	0.10
Repair maintenance $ (1.2%/p/100 hrs, reaper 7 %/P/100 hrs)	0.78	0.76	0.84
Total fixed cost, $/hr	1.64	1.70	1.87
Fixed cost (Reaper and tractor), $/hr		3.33	1.87
Field capacity, hr/ha		2.94	5.26
Skilled labour input, man-hr/ha		3	5
Fuel consumption. Ltr/ha		12	3.94
Costs, $/ha			
Fixed cost (Including repair), $/ha		9.82	9.85
Labour@0.27/hr, $		0.82	1.36
Fuel (Diesel/kerosene) (@) 0.52/0.33/litre, $		6.26	1.28
Lubricants (20 % of fuel cost), $		1.25	0.26
Total cost, $/ha		18.15	12.75

Field Grain Losses

The field grain losses were similar to sickle harvesting. The field losses depended on variety, maturity, field condition, speed of machine and time of harvest. The shattering loss due to operation of the machine was negligible if the crop were harvested in time. However, the shattering loss increased when the crop was over matured. Harvesting loss for the tractor-mounted reaper was 0.2-0.3 %, whereas the same for self propelled reaper was 0.2-0.4 %.

Cost of Harvesting

The cost of harvesting for manual reaping consisted of the wages paid for cutting the crop, gathering and bundling (**Table 3**), and, in some cases, transportation to the farm yard. For mechanical harvesting, the cost included the depreciation, interest, repair and maintainance of the machine as well as the cost of manpower for pre-harvest operation such as cutting the sides and corners of the plot, operator's wages and cost of fuel (**Table 1**). The purchase cost of the self-propelled, walking-type KAMCO reaper was $1196 and that of the tractor mounted reaper was $1087. The purchase cost of the tractor was $6522. The cost of skilled labour for the tractor-mounted reaper was $ 0.81 per hectare and the unskilled labour cost was $10.65 per hectare. The total labour cost for the tractor-mounted reaper was

$11.46 per hectare. The total cost of harvesting that included the cost of tractor, reaper, fuel, and labour was $28.76 per hectare. The cost of skilled labour for the self-propelled, walking-type reaper was $1.43 per hectare and that of unskilled labour was $10.65 per hectare. The total cost towards labour charges, thus, was $12.07 per hectare. The total cost of harvesting by the self-propelled reaper that includes the machine, labour charges and fuel charges was $23.36 per hectare. The harvesting cost manually by sickle was $45.65 per hectare.

Farmer's Opinion on the Reaper

The farmer's are convinced that the cutting of crop by reaper is much faster than manual cutting by sickle. The contract labourers are willing for cutting, collecting and transportation but are unwilling for collection and transportation as they get less wage through that.

The local supplier of the reaper only sells the machine and has no spare parts or know how in case of breakdown. Local repair of the machine at the farmer's place is well neigh impossible. The reaper cuts the crop 10-15 cm above the ground level. Hence, the stubbles pose a problem for seedbed preparation and is not liked by the farmers.

In most cases, the crop lodges before harvesting. Lodged crop is difficult to harvest by the machine. The farmers are not aware of the requirements of the machine and there is standing water at the time of harvesting. The reaper cannot work unless the field is dry so that it can sustain its weight. The farmers' plots are not consolidated and the same area has different ownership. Hence, approach roads to the mature crop is lacking, which hinders the use of the machine.

Conclusions

The cost of reaping alone by tractor mounted reaper and self-propelled reaper was 50 % and 30 % of the manual reaping, respectively. The total cost of harvesting by tractor mounted and self-propelled reaper was 63 % and 51 % of that of manual harvesting, respectively. The total manpower requirement for harvesting by tractor mounted and self propelled reaper was 25 % and 26 % of manual harvesting, respectively. Harvesting loss by mechanical reaping was limited to 0.4 % and was at par with manual harvesting.

Initially, the farmers' response was positive, since it required less manpower and reduced harvesting cost drastically. However, any break down gives a set back to the harvesting operation. Lack of after-sales service and unavailability of spare parts does not lure the farmers to go for mechanical harvesting. Fragmentation of holdings and lack of approach roads to the harvestable plots stand in the way of adoption of mechanical reaping.

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■■

Table 2 Labour input in harvesting operation, man-hour/ha

Item	Manual	Tractor mounted reaper	Self propelled reaper
Manual cutting of sides and corners of the plot	-	8	8
Reaping	192	2.94	5.23
Collecting, bundling etc	48	48	48
Total	240	59	61

Table 3 Total cost of harvesting by different methods

Cost item	Manual	tractor mounted reaper	Self propelled reaper
Reaping; $/ha	35	18.10	12.71
Gathering, bundling etc; $/ha	10.65	10.65	10.65
Total cost of harvesting; $/ha	45.65	28.75	23.36

Structure, Management, Operation and Mechanization Possibilities of the Irrigation Systems in Turkey

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Abstract

Almost all of the irrigated agricultural land in Turkey is served by open-canal gravitational systems. Water in these systems is regulated by hand-operated gate control and measurement. Nearly all of these systems were constructed by the State Water Works (DSI). From 1993 onwards, transfer of operation and maintenance of these systems to water users' organizations, principally irrigation associations, was accelerated. At present this work is to the point of completion. This paper seeks to evaluate the structural, management, operational and mechanization status of these systems, both before and after the handover. And further to point out the problems that arise from structure and management that need to be overcome for the success of sustainable water management in the operation of these systems, and emphasizing suggested solutions to these problems: financial measures for renovation and modernization; legal measures such as reforms to facilitate the organization of the associations; and educational measures to train farmers and personnel in irrigation.

Introduction

Water resources in the world are both reducing and being polluted due to the increase in irrigated agricultural lands, industrial development and irregular urbanization. By the year 2000, world population reached 6 thousand million and, the forecast for 2025 is 8 thousand million or more. Therefore, importance of conservation of water resources both quantitatively and qualitatively appears spontaneously.

Amount of water allocated to agricultural use reduces as demand for drinking and domestic water of the urban and industrial sector increase. While the part of agriculture in the total water use in the early 1900s was 90 %, it was about 60 % at the beginning of the 21st century. Nevertheless, the industry part raised from 6 % to 24 %. Therefore, there is a need for increasing efficiency of irrigation management and use of soil and water resources. The most important factors providing efficiency in irrigated agriculture are irrigation systems which affect sustainable use and development of available soil and water resources.

Since Turkey is in the way of membership to the European Union and in face of a strong competition with the other member countries, studies related to the agricultural sector, including establishment of modern irrigation infrastructure, development of operation and management of these are accelerated. The studies in this area are carried out by the private sector (farmers and groups of farmers) and the public sector (such as General Directorate of State Hydraulic Works (DSI) and General Directorate of Rural Services (GDRS).

The average annual precipitation of Turkey is 643 mm, which corresponds to a water potential of 501 km^3 per year. Runoff amounts to 238 mm, an average rate of 37 %, and the remaining 63 % is lost to evapotranspiration. A certain amount of the runoff is allocated to meet the water rights and requirements of the neighboring countries. Consequently the amount of surface water utilized for consumptive purposes is 95 km^3 per year. According to the studies based on groundwater resources, the total safe yield of groundwater resources is estimated to be 13.66 km^3. The potential of total available water resources from surface flow and groundwater would amount to 108.66 km^3 per year (DSI, 2004).

The total area of Turkey is approximately 77.95 million ha, of which about 28.05 million ha is arable land. Of the arable land, 25.85 million ha are irrigable land and 2.20 million ha are non-irrigable. The gross area which can be developed for irrigation is estimated by the DSI at 8.5 million ha, of which about 4.7 million ha has been developed. The remaining area of about 3.8 million ha is yet to be developed for irrigation (DSI, 2003).

The present work consists of an evaluation of the structural, management, operational and mechanization status of these systems, both before and after handover.

Structural Situation of the Irrigation Systems

The critical growing period for most of the crops is during the months of June, July and Augusts when most of the rivers carry base flows only. Water storage, therefore, is indispensable. About 80 % of major irrigation projects are fed with water from reserves or lakes. Large-scale irrigation projects are carried out by DSI. The main irrigation structures such as dams, canals and control structures are constructed under the supervision of DSI. Small scale irrigation projects and on-farm water development works are carried out by GDRS (Tekinel, 1994).

At the end of 1999 the number of small and large dams in operation and under construction by DSI were 512 and 267, respectively (DSI, 2000). At the beginning of 2000, 2498 small earth dams were constructed by GDRS (KHGM, 2000).

The 95 % of irrigation systems in the country consist of open canal systems (or gravity systems) (Acatay, 1996). In general a reservoir such as a dam or bend is the beginning of these systems. Water is taken from the reservoir by diversion structures such as a regulator or weir and is conveyed to carrying canals, which reach the irrigation area by distribution canals and the following canals. In a water distribution system, the cross section of the main and secondary canals is trapezoid. Tertiary canals are both trapezoid and U-canals. Most current systems are old, and in urgent need of maintenance and renovation. In these old systems, especially those with earth canals, there are serious structural problems such as shortcomings in water control, measurement structures and equipment in secondary and tertiary canals. These kinds of problem make water management difficult and reduce performance in water distribution. However, since the 1990s, the question of economy in water use in this country has come to the forefront, and technology has advanced, so that the DSI has started widespread introduction of pressurized irrigation networks (DSI, 2003).

In water distribution system canals, water regulation is done on the basis of upstream control. Control structures are equipped with mechanical parts such as bolted or segment gates which are operated by human or motor power in situ. In the system, water cannot be distributed evenly. Also, the upstream water control causes water to be wasted by discharge and drainage problems in the irrigation areas. For solving these problems in the former and new systems, the new gate systems with downstream control were considered (Sayin and Bayrakci, 1994) and development attempts were started. Furthermore new water regulation was realized in the irrigation systems of GAP (Unal et al., 2001).

Inlets are used for controlling and measuring distribution of water in the systems. The structures used to take irrigation water to main and secondary canals, to tertiary canals and to the field are the high flow intakes (> 1 m^3/s), the constant upstream level gates (0.06-1 m^3/s) and the outlets (or farm turnouts), respectively. Because the required slope could not be provided, the weirs such as cipolletti, poncelet and triangular weirs, are not used in the systems currently (Bilen 1988; Cevik and Tekinel 1990; Avci and Unal 1994).

The fact that constant upstream level gates could not be used in the former systems caused the irregular changes in water levels in tertiary canals especially throughout irrigation seasons. Assembling Replogle weirs at the head of secondary

Table 1 Areas opened to operation and handed over, by year

Year	Area opened to operation, ha	Area handed over, ha	Rate, %
1993	1,527,239	72,042	5
1994	1,561,841	267,362	17
1995	1,619,070	978,575	60
1996	1,688,861	1,190,334	70
1997	1,740,223	1,279,039	73
1998	1,809,687	1,483,931	82
1999	1,842,906	1,529,454	83
2000	1,875,104	1,618,669	86
2001	1,908,854	1,663,730	87
2002	1,967,475	1,704,475	87

canals and using Neyrpic orifices at the head of tertiary canals were suggested for the solution of this problem (Burton, 1992).

In these old irrigation networks, amounts of water delivered to tertiary canals and to the land goes unmeasured, while water supplied to main and secondary canals is generally measured with a non-recording staff gauge. However, the regular and speedy measurement of irrigation water delivered to the canals is not possible, nor can the administration closely follow water delivery. Recently new technology (electronic limnigraphs with or without GSM modems) has been introduced for the monitoring and measurement of water level to facilitate water management in irrigations reservoirs (dams and regulators) in Turkey. This technology has been put to increasing use in main and secondary canals of irrigation systems since 2000.

Managerial Situation of the Irrigation Systems

Irrigation water management is a wide concept including facilities which distribute irrigation water and operation, maintenance and improvement of these facilities.

Effective and productive irrigation can be provided with participation of the farmers in irrigation water management. The studies on farmer participation in the irrigation projects took part in Government policies for the first Five Year Development Plan (1963-1967). A precondition of the Development Plans was establishment of irrigation unions by the farmers for the new and former irrigation systems. The main reason for considering the transfer program has been the operational and maintenance (O&M) cost met by DSI and the Government. The O&M cost recovery, largely due to political reasons, has been unsatisfactory (about 30 %). Considerable increase in the cost of O&M due to the role of unionized labor further aggravated the situation.

A rapid transfer to the irrigation associations of responsibility for operation, maintenance and administration of irrigation systems constructed by the DSI began in 1993. The total area of fully transferred schemes had merely reached 72,000 ha by mid-1993. **Table 1** shows changes in land brought under irrigation by the DSI and land handed over between 1993 and 2002. (DSI, 2003). In July 1993, the World Bank's cooperation in promoting the transfer program was initiated. By 2003, responsibility for operation, maintenance and administration of 89 % of irrigated land that had been brought into operation by the DSI (1,704,469 ha) had been transferred to foundations and institutions formed by those benefiting, such as village authorities, municipalities, irrigation associations or cooperatives. The greatest share (91 %, or 1,551,262 ha) went to irrigation associations (Ince et al., 2003) (**Table 2**).

Responsibility for management of the water in the irrigation systems belongs to the DSI at the main canal level, to irrigation associations at the secondary canal level, and at tertiary canal level to village irrigation groups who are themselves responsible to the irrigation associations.

In Turkey, planned programmes are made to keep the water-yield relationship at the desired level, to prevent problems in areas such as salinity, alkalinity, ground water or erosion, to obtain maximum benefit per unit of area and per unit of water, and to ensure delivery of available irrigation water to the whole system on the basis of dependability, sufficiency and equity. Planned water delivery is carried out according to overall irrigation planning and water delivery programmes.

Overall irrigation planning, as practiced by the DSI, and as it continued to be practised since takeover, is carried out prior to the irrigation season by the DSI and the irrigation associations working together. This planning aims to determine the amounts of water to be delivered to the associations in the course of the irrigation season by matching the associations' demands for irrigation water with amounts of water in the reservoirs, and canal capacities. Water delivery programmes prepared during the irrigation season are intended to prioritize farmers' daily water demands, and to allow them to obtain water on time and in an ordered way.

The distribution of irrigation water in the country is done with respect to the semi-demand method with water regulation structures of upstream control. According to this method the farmers take irrigation water in a limited amount for a period of a few days. The prices of irrigation water are determined again in every year by the factors such as irrigated area, and plant species grown. This case has caused the farmers at the beginning of canal to use excess water and, in spite of this, the farmers at the end of the system suffer from water scarcity. To solve these problems it is of particular importance that water distribution should be according to the

Table 2 Distribution of irrigation systems handed over, by recipient organization

Organization	Unit	Rate, %	Area, ha	Rate, %
Irrigation association	299	42.3	1,551,262	91.0
Village authority	214	30.3	34,238	2.0
Municipality	134	19.0	56,588	3.3
Cooperative	56	7.9	61,349	3.6
Other	4	0.6	1,038	0.1
Total	707	100.0	1,704,475	100.0

demand (in m^3). This should enable farmers to use the amount of water needed when they need it and to participate in the water distribution. In case of change in water distribution method, the selection of suitable control and measurement structures and determination of the places to be assembled in the system is also important (Avci and Unal, 1994).

Operational Situation of the Irrigation Systems

In assessing the success rate or performance of irrigation operation, various indicators such as irrigation ratios, irrigation efficiency and revenue ratios have been widely used. Available results relating to observations by the DSI of irrigation systems handed over to the associations and to their operational performance are evaluated here. Management performance indicators are higher in systems handed over to irrigation associations than in systems operated by the DSI. In 1999, the irrigation ratio of irrigation systems operated by the DSI was 41 %, but it was 70 % in systems which had been handed over. Irrigation efficiency in DSI-operated systems was 31 %, but 41 % in handed-over systems. In DSI-operated systems revenue ratio was between 36 and 41 %, but systems which had been transferred achieved above 90 % (Beyribey et al., 2003).

Work evaluating 1996 performance found that in 15 irrigation systems operated by irrigation associations, irrigation ratios prior to handover was 70 %, but 78 % after handover. This rise in irrigation ratio is seen as a success for irrigation management by participants. Pre-handover and post-handover values of profitability ratios, showing economic efficiency, and of financial activity ratios in these systems are 4.2 and 5.2, and 51 % and 35 %, respectively. The rise in profitability ratio after handover was attributed to more efficient use of water in the system, while the fall in financial efficiency was attributed to the insufficiency of income derived from irrigation water to meet operation and maintenance costs (Beyribey et al., 1997).

In many works to determine system performance, performance was found to be low for reasons relating to quality of construction and operation. These works mention insufficiencies in measurement and control structures and equipment, insufficient capacity in transmission and delivery canals, and excessive losses due to leakage as structural problems, while management shortcomings include the lack of dependable, equitable and efficient delivery, the inability to exercise effective control over gate operation, and the inability to provide adequate maintenance (Avci et al., 1998; Beyazgul et al., 1999; Murray-Rust and Svendsen, 2001; Cakmak, 2002; Unal et al., 2004).

In works which monitored and evaluated operation of the systems by irrigation associations, it was determined that there were problems with determining water charges and their payment, from the point of view of preventing excessive water use and that neither farmers nor technicians had sufficient knowledge of irrigation. Also, different associations using the same water source were insufficiently coordinated, the machinery fleet necessary for maintenance was insufficient, and there were legal deficiencies in the setup of the associations. It was stressed that these problems hindered successful administration of the system (Arca et al., 2001; Kiymaz et al., 2003). The success of an irrigation association depends on suitable irrigation planning and making a water delivery programme, while, at the same time, implementing them in a fair way. However, works on this subject cite insufficient planning and delivery by the associations as reasons for income losses related to reduction in fertility of irrigated areas, along with environmental problems such as soil erosion, high ground water levels, and desertification (Beyribey et al., 2003). When irrigation water needs and amounts supplied are examined in both DSI-controlled systems and those which have been handed over, amounts of water supplied are far greater. That is, there is an excessive use of water (**Table 3**). The main reasons for this are that water losses in the system are very large, and that farmers do not understand enough about irrigation (Cakmak et al., 2003).

Works which evaluated farmers' reactions after the handover of irrigation systems found that although water delivery in the systems operated by the associations was flexible, it was not equitable or dependable, nor was maintenance work sufficient (Koc, 2001; Guvercin and Boz, 2003; Unal et al., 2004).

In systems that have been handed over, the age of their distribution networks makes maintenance and modernization of the networks necessary. This necessity encourages

Table 3 Water needs and water supplied, for DSI-controlled networks and transferred networks

Year	Irrigation water need, m^3/ha		Irrigation water supplied, m^3/ha	
	DSI	Transferred	DSI	Transferred
1995	3,915	4,342	10,642	8,885
1996	4,736	4,540	11,022	10,206
1997	4,535	4,469	12,852	9,921
1998	3,754	4,683	13,084	10,598
1999	4,071	4,511	13,182	11,154
2000	3,979	4,529	11,936	10,849
2001	3,507	4,705	9,281	10,849

the associations to use up-to-date technology in their operation, maintenance and management. In the past few years, especially in organizations with strong financing, renovation work has been accelerated, and telemetric systems such as electronic limnigraphs with or without GSM modems have been brought into use for real-time measurement and monitoring of irrigation water in transmission and distribution canals (Asik et al., 2003).

Mechanization Possibilities in Maintenance of the Irrigation Systems

The extension of irrigation and drainage networks depends on maintenance and maintenance work, which, in turn, depends on the existence of work machinery. In systems transferred to the irrigation associations, maintenance was carried out in the first years after handover using machines provided by the DSI and other organisations, and later with machines either bought or hired by the associations, a practice which continues today.

Machines for the upkeep of irrigation and drainage canals are considerably expensive. For this reason, it is not easy to extend the fleets of machinery owned by the associations. Financially strong associations are rapidly extending their machinery fleets by increased purchases, while others are hiring machinery. This situation can be seen clearly in **Table 4**, which shows the machinery fleets of the 13 irrigation associations of the Gediz basin area, one of the largest in Turkey. Their machinery fleets in 2003 show great advances compared to 1996, when transfer work was completed. In addition, it can be seen that development of associations with large irrigation areas and therefore greater financial power has been greater (**Table 4**).

Insufficient maintenance work is one of the factors which decrease system performance. This is closely related to an association's inadequate possibilities for mechanization. In order to overcome this kind of problem, there is a need to increase credit facilities for associations to extend their machinery fleets, and to set up organisations to facilitate the shared use of machinery between organisations.

Conclusions

The results obtained in a short time since accelerated handover operations were begun in this country in 1993 have been recognized as a success by international bodies. In this connection, the World Bank has held Turkey up as a model to Balkan, North African and Middle Eastern countries, and to the Central Asian Turkish republics. In spite of this, operation of irrigation systems that have been handed over to the associations has not reached the desired level of success. This derives from structural and management problems. The associations are devoting much effort to address these problems. In order for these efforts to be successful, that is to operate the system so as to use our natural resources sustainably, the following steps are suggested:

- Maintenance and modernization work on irrigation systems should be accelerated and carried out on a wider basis.
- Machinery fleets should be extended.
- Irrigation staff and farmers should be trained.
- The legal basis of the associations should be strengthened.

The implementation of these solutions depends on three things: the associations should have extra financial resources in addition to their own budgets; necessary revisions need to be made in the law; and effective training programmes need to be started by irrigation experts.

Table 4 Machinery fleets of the irrigation associations of the Gediz basin area

Irrigation association	Irrigated area, ha		Total length of irrigation and drainage canals, km	No. of melioration machine		Length of canal per unit of machinery, km/unit	
	1996	2003		1996	2003	1996	2003
Salihli sag sahil	9,101	9,101	571	-	5	-	114.2
Salihli sol sahil	9,237	9,210	529	-	4	-	132.3
Ahmetli	3,275	3,275	188	-	2	-	94.0
Gokkaya	997	997	70	-	-	-	-
Turgutlu	12,102	12,102	426	1	3	426.0	142.0
Mesir	6,382	13,679	725	2	6	362.5	120.8
Sarikiz	13,702	13,702	586	4	8	146.5	73.3
Gediz	10,962	10,962	562	2	5	281.0	112.4
Menemen sag Sahil	6,365	6,365	400	-	2	-	200.0
Menemen sol Sahil	16,500	16,500	694	1	7	394.0	99.1
Bag	4,486	4,487	184	-	1	-	184.0
Uzum	6,930	6,930	260	1	2	260.0	130.0
Sarigol	1,927	1,927	82	-	2	-	41.0

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Effect of Operating Parameters and Pesticide Flow Characteristics on Performance of Air Assisted Spraying

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Abstract

The safe and efficient application of pesticides requires, among other things, the definition of an appropriate droplet size spectrum. The ideal spectrum will maximize spray efficiency for depositing and transferring a lethal dose to the target, while minimizing off-target losses such as spray drift and user exposure. The effect of spray fluid discharge rate, height and orientation of nozzle and operational speed depositional characteristics of spray on both artificial plants (plastic leaves) and potted plants was quantified to ensure for maximum spray coverage. The laboratory experimental set up consisted of blower assembly, fluid flow regulator, nozzle height and orientation adjustments that were developed for the study. The trace wash procedure with methylene blue dye as tracer was used for sample extraction and the amount of deposition was calculated by spectrophotometer. Filter paper 5 x 5 cm was used for sample collection. The droplet size (VMD) was measured by 'IMAGE ANALYSER' software from the samples collected on bromide paper 5 x 5 cm.

The deposition efficiency of spray reduced with the increment in discharge rate of spray fluid at slow forward speeds (1.0 and 1.5 km h^{-1}) and increased with the increment in discharge rate of spray fluid at the higher forward speed (2.0 km h^{-1}). It showed a declining trend as the forward speed increased. It was maximum at 50 cm nozzle height from the canopy and showed a declining trend at both upper and lower heights. The deposition efficiency at nozzle orientation of 60 degrees with the vertical showed the maximum for all the combinations of discharge rate, height of nozzle and forward speed of operation. As the discharge rate increased, the droplet size also increased irrespective of height and orientation of nozzle. The effect was considerably high at a nozzle height of 25 cm. The size of droplets formed was at the recommended level (100 to 200 μm). The droplet size was minimum (150 to 175 μm) at nozzle height of 50 cm.

Introduction

Air assisted sprayers are the most commonly used spray equipment in cotton foliar applications. They use high velocity air to transport the droplets from the nozzles to the tree canopy. The droplets are entrained in a turbulent air flow and their deposition depends on the air flow characteristics of the sprayer, droplet size spectrum, operating parameters, pesticide flow characteristics, canopy structure, and weather conditions. A proper combination of the above factors can improve the coverage and increase the efficiency of pesticide application. The present study was undertaken to quantify and optimize the effect of these factors towards the development of a best suited sprayer for cotton in Indian conditions.

Review of Literature

The smallest drops provided the best control, but also were subject to excessive drift; and hence a droplet size between 140 and 200 μm was recommended Smith et al. (1975). An image analysis system for quantifying droplet deposition system was developed by Sistler (1982). The system used a video camera to digitize an image of dye droplets on a sample card and the microprocessor calculated areas and diameters of droplet images, number of droplets per unit area, and the percent of spray droplets across the spraying swath. A relatively simple and fast method of quantitative and qualitative evaluation of spray application based on deposit and coverage measurements on artificial targets was proposed for small scale comparative field experiments with air-assisted orchard sprayers by Rocamora et al. (2002).

The nozzle position (Bintner et al., 1977) and height had a strong effect on spray distribution uniformity and its application efficiency (Wang et al., 1995). The changes in ground speed made it impossible to maintain a constant application rate (Gaadi and Ayers, 1994). It decreased dramatically as the travel speed increased (Pillai et al., 1999).

Materials and Methods

The projected area, width and height of the plant canopy were measured from the field at different growing stages of two ruling varieties of cotton in Tamil Nadu viz, MCU 5 and MCU 12. The heights of the randomly selected plants were measured with scale and 'T' square. Width of plant canopy was quantified by the photographic method. The photographs were taken at known heights from the plant canopy and at angles of 45, 60 and 75 degrees with the vertical plane simulated to the position of the spray nozzle. The outer boundaries of the plant canopy were marked and the maximum widths were measured. By multiplying with the scale factor, the original width of the plants were calculated and averaged (Byers et al., 1984).

The projected area of the plant canopy is the two dimensional virtual area of plant canopy which obstruct the beam of spray (French et al., 1992). The nozzle selected for the present study was standard ASPEE Bolo power sprayer nozzle. Four levels of spray fluid discharge rates were selected for the study as 200, 300, 400 and 500 ml min^{-1} (application rate varies between 80 to 400 l ha^{-1}) based on the previous research work. The operational speed was selected as 1.0, 1.5 and 2.0 km h^{-1}, the normal walking speed of a man. The effect of orientation of nozzle from the canopy on amount of deposition of spray and droplet sizes were investigated by keeping levels of orientation viz, 45, 60 and 75 degree with the vertical plane.

Deposition Efficiency of Spray

Spray deposition on the target was quantified using the tracer wash procedure (Law and Cooper, 1988 and Juste et al., 1990). The procedure consisted of spraying a tracer solution (water with Methylene blue dye) of known concentration on the targets, after placing a removable, sampling surface of known area (filter paper of area 50 x 50 mm) on the target (Holownicki et al., 2002). The deposited tracer on the samples was recovered by a wash procedure. The concentration of recovered tracer solution was determined as its optical density by using a pre-calibrated spectrophotometer. This was, in turn, used to compute the quantity of spray fluid deposited from the correlation obtained between known concentrations and optical densities.

Droplet Size Determination

A 50 x 50 mm glazed bromide paper that was used as the sampling surface was pasted to the targets for capturing the spray droplet sizes (Holownicki et al., 2002). The recovered bromide papers were scanned and saved as Bitmap images and were analyzed in the software 'IMAGE ANALYSER 1.20.2' developed by MeeSoft. To get the VMD of the spray droplet directly, a reference scale of known diameter was introduced.

Laboratory Experimental Set Up

An experimental setup was developed to study the spray deposition characteristics of air-assisted spray as influenced by the selected factors under laboratory conditions. It consisted of a trolley made from mild steel pipes 25 mm inside diameter and 'L' angle of dimensions 25 x 3 mm with the overall dimensions 630 x 260 x 250 mm. that was the base frame over which the all other accessories were mounted (**Fig. 1**). Two pneumatic wheels were provided on either side of mainframe to provide free forward and reverse movement of the system. The prime mover for the blower was a petrol start kerosene run, 0.5 hp, single cylinder, air-cooled engine (Make: Honda; Model: GK100) with a rated engine rpm of 3,600.

A power sprayer blower with a centrifugal entry type impeller and volute type casing was used to generate an air jet for spray atomization and was fastened to the main frame of the trolley. The drive from the engine was transmitted to the center shaft of the blower by means of 'V' belt ('A' type) and pulley arrangement. The impeller speed was set to 5,500 rpm. The nozzle of ASPEE Bolo motorized knapsack mist blower was used to apply the spray and was connected to the blower outlet by a corrugated flexible hose 60 mm diameter. The experiment was conducted on potted plants of 40 to 60 days age and artificial plants made from the plastic sheet of 0.3 mm thickness (Rocamora et al., 2002) to optimize the variables.

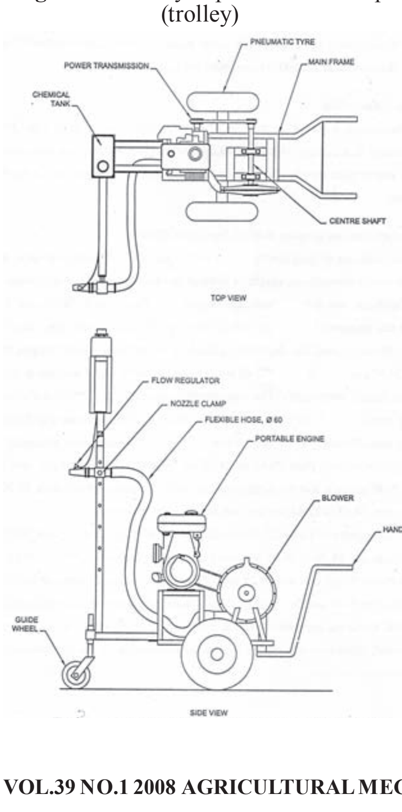
Results and Discussion

The average height of the plant was 112.0 and 120.0 cm for MCU 5 and MCU 12, respectively. The average width of plant canopy was 58.0 and 60.0 cm, respectively. Projected area of plant canopy that obstructed the spray was 75 to 85 % of the total spray swath.

Effect of Discharge Rate of Spray Fluid on Deposition Efficiency

The influence of fluid discharge rate on the deposition efficiency of spray with respect to nozzle orientations, height of nozzles and forward speed of operations for both the artificial and potted plants are depicted in **Figs. 2** to **4**. While the fluid discharge rate increased from 200 to 500 ml min^{-1} at 45 degree nozzle orientation and 1.0 km h^{-1} forward speed, the deposition efficiency on artificial plants changed from 26.64 to 24.87 %, 29.71 to 28.43 % and 30.39 to 26.42 % at 25, 50 and 75 cm height, respectively. The corresponding changes for deposition efficiency on potted plants were 27.60 to 24.83 %, 26.51 to 27.53 % and 25.84 to 26.52 %. Similarly at 60 degree and 1.0 km h^{-1}, the deposition efficiency for artificial plants reduced from 29.42 to 28.24 %, 36.22 to 34.09 % and 29.36 to 29.49 %, respectively, and the corresponding values for potted plants were 28.20 to 27.84 %, 34.47 to 32.44 % and 28.53 to 28.30 %.

Fig. 1 Laboratory experimental set-up (trolley)



At 75 degrees and 1.0 km h^{-1}, these values were 28.16 to 26.34 %, 33.20 to 27.55 % and 28.29 to 24.84 % for artificial plants and 27.21 to 25.16 %, 30.54 to 26.51 % and 25.33 to 25.53 % for potted plants, respectively for the above height of nozzles. Though there was reduction in deposition efficiency at lower speed, it was not pronounced. However, at a higher speed of 2.0 km h^{-1}, as the discharge rate increased, deposition efficiency increased at all the combinations of the experimental variables.

The reduction in deposition efficiency at higher fluid discharge rates may be explained by the spilling off of spray fluid from the leaf surface after rejoining of droplets at slow forward speed of operation. At higher forward speeds the exposure time of canopy to the spray reduced and, moreover, the agitation of canopy by the air jet was observed to be irregular which resulted in variation of deposition efficiency without a definite trend. The similar trend of the relationship was observed for both artificial plants and potted plants with negligible reduction in deposition efficiency for the latter. The lower value of deposition efficiency may be due to the difference in morphological features of the original and artificial leaves such as surface roughness pattern and rate of deflection (Franz et al., 1998).

Effect of Forward Speed of Operation on Deposition Efficiency

Deposition efficiency reduced as the forward speed increased at all the combinations of the nozzle height, orientation and discharge rates (**Figs. 2** to **4**). For a discharge rate of 200 ml, nozzle orientation of 45 degrees and speeds of 1.0, 1.5 and 2.0 km h^{-1} the decrease in deposition efficiency for artificial plants varied from 26.64 to 20.59 %, 29.71 to 22.62 % and 30.39 to 17.58 %. The corresponding values for potted plants were 27.60 to 21.43 %, 26.51 to 23.51 % and 25.84 to 18.24 %. At 60 degrees nozzle orientation the corresponding values varied from 29.42 to 20.58 %, 36.22 to 28.65 % and 29.36 to 22.65 % for artificial plants and 28.20 to 20.93 %, 34.47 to 20.93 % and 28.53 to 21.79 % for potted plants and from 28.16 to 18.57 %, 33.20 to 19.35 % and 28.29 to 22.57 % for artificial plants. The variation was 27.21 to 18.76 %, 30.54 to 19.39 % and 25.33 to 22.56 % for potted plants at 75 degrees for the nozzle heights of 25, 50, 75 cm, respectively.

This declining trend of deposition efficiency may be due to reduction in exposure time and irregular deflection of crop canopy to the spray at higher operating speeds. Moreover, the deflection of spray jet from the line of travel was observed at higher forward speeds and resulted in reduction of deposition efficiency. The trend of the relationship was same for both artificial plants and potted plants with negligible reduction in deposition efficiency for the latter.

Effect of Height of Nozzle from the Canopy on Deposition Efficiency

The change in deposition efficiency with the change in nozzle orientation is depicted in **Figs. 2** to **4**. Spray discharge of 200 ml min^{-1} and speed of 1.0 km h^{-1}, and for 25 cm height, deposition efficiency of spray for artificial plants was 26.64, 29.42 and 28.16 %, respectively, for 45, 60 and 75 degree nozzle orientation and the corresponding values for potted plants were 27.60, 28.20 and 27.21 %. When the height increased to 50 cm, the corresponding values were 29.71, 36.23 and 33.20

% for artificial plants and 26.51, 34.47 and 30.54 % for potted plants. For 75 cm height, they were 30.39, 29.36 and 28.29 % for artificial plants and 25.84, 28.53 and 25.33 % for potted plants, respectively, for the above nozzle orientations. Similar trends were observed for all other treatment combinations. From these data it is clear that deposition was maximum at 60 degree nozzle orientation for all the treatments.

At the height of 25 cm from the canopy, the formed spray droplets will not get enough time to suspend in the air stream because the travel distance between the nozzle tip and the target was too low and will be transported to the ground rather than the plant. At height of 75 from the canopy the exposure of droplets to the extraneous parameters such as temperature and drift was greater and resulted in lower deposition efficiency (Cenkowski et al., 1994). At higher fluid discharge rates of 400 and 500 ml min^{-1}, the effect was minimum with 5 % variation and the same trend.

Effect of Nozzle Orientation on Deposition Efficiency

At all the treatment combinations the deposition efficiency was found to be maximum when the nozzle height was fixed at 50 cm (**Figs. 2** to **4**). Keeping the discharge rate at 200, nozzle orientation at 45 degrees and speed at 1.0 km h^{-1}, deposition efficiency was 26.64, 29.71 and 30.39 % on artificial plants and 27.60, 26.51 and 25.84 % on potted plants, respectively. However, at 60 degrees, the corresponding values were 29.42, 36.22 and 29.36 % on artificial plants and 28.20, 34.47 and 28.53 % on potted plant targets. At 75 degrees these values were 28.16, 33.20, 28.29 % on artificial plants and 27.21, 30.54 and 25.33 % on potted plant targets, respectively, for

Fig. 2 Effect of spray fluid discharge on deposition efficiency nozzle orientaion 45 degree (AP: Artificial poiny, PP: Potted plant)

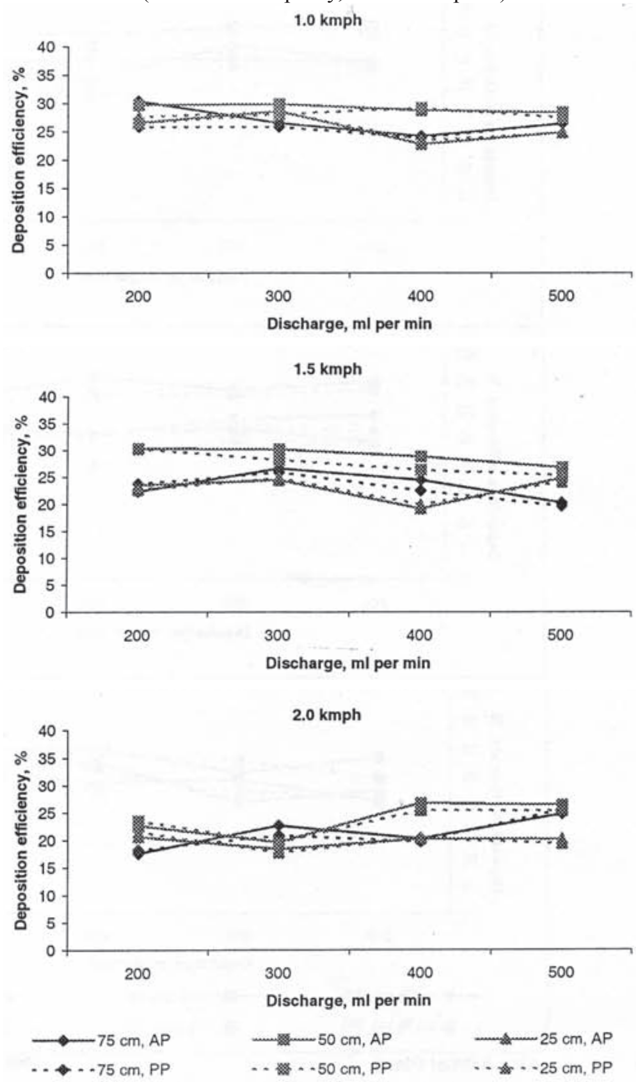
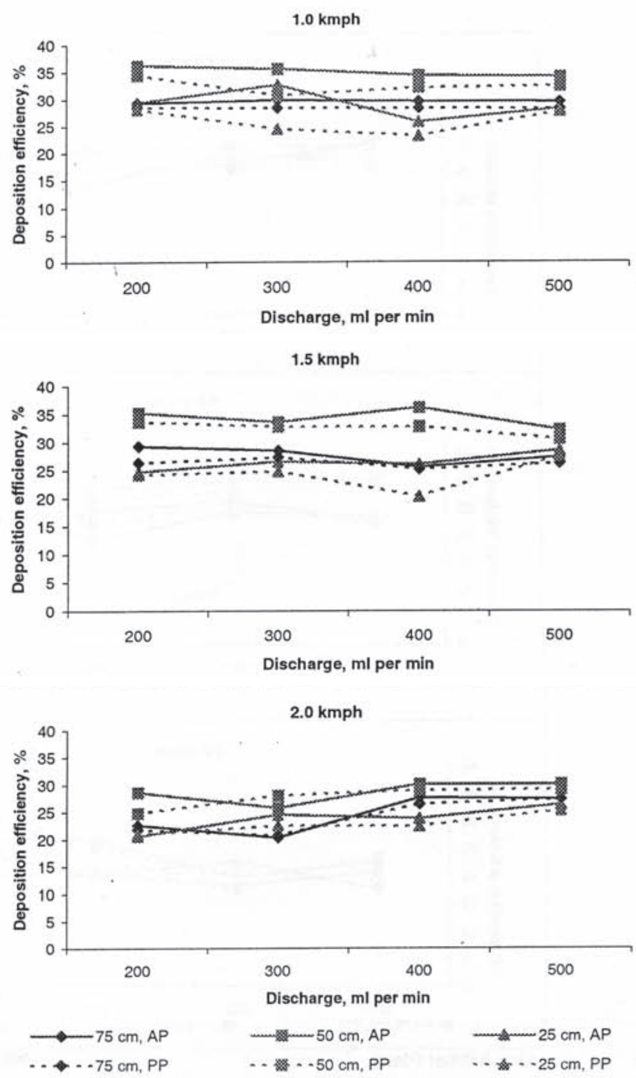


Fig. 3 Effect of spray fluid discharge on deposition efficiency nozzle orientaion 60 degree (AP: Artificial poiny, PP: Potted plant)



25, 50 and 75 cm height of nozzles. The same trend was also observed for other treatment combination.

The reduction in the amount of deposition at 45 degree nozzle orientation could be explained by the throwing of droplets to the ground. At 75 degree nozzle orientation the reduction in deposition efficiency of spray could be explained by the over exposure of droplets to the extraneous parameters such as temperature and drift. The trend of relationship was similar for both artificial plants and potted plants with negligible difference.

Effect of Spray Discharge Rate on Droplet Size

Discharge rate of spray fluid had pronounced effect on droplet size (**Fig. 5**). As the fluid discharge rate increased from 200 to 500 ml min^{-1}, at 45 degree nozzle orientation, the droplet size of spray on artificial plants changed from 176.09 to 235.19 µm, 164.13 to 162.74 µm and 162.55 to 182.78 µm while the corresponding values on potted plants were 173 to 251.25 µm, 155.00 to 188.69 µm and 159.24 to 191.01 µm at 25, 50 and 75 cm height, respectively. Similarly at 60 degrees, droplet size obtained on artificial plants increased from 164.11 to 223.77 µm, 155.30 to 179.34 µm and 153.33 to 188.80 µm with corresponding values for potted plants of 162.74 to 238.57 µm, 162.37 to 181.57 µm and 159.74 to 187.27 µm. At 75 degrees, these values were 162.00 to 232.54 µm, 160.12 to 187.33 µm and 148.62 to 195.74 µm for artificial plants and 167.49 to 238.07 µm, 155.34 to 184.12 µm and 149.12 to 195.64 µm for potted plants, respectively, for the above height of nozzles.

As the discharge rate increased the droplet size also increased irrespective of height of nozzle. The effect was considerably higher at a

Fig. 4 Effect of spray fluid discharge on deposition efficiency nozzle orientaion 75 degree (AP: Artificial poiny, PP: Potted plant)

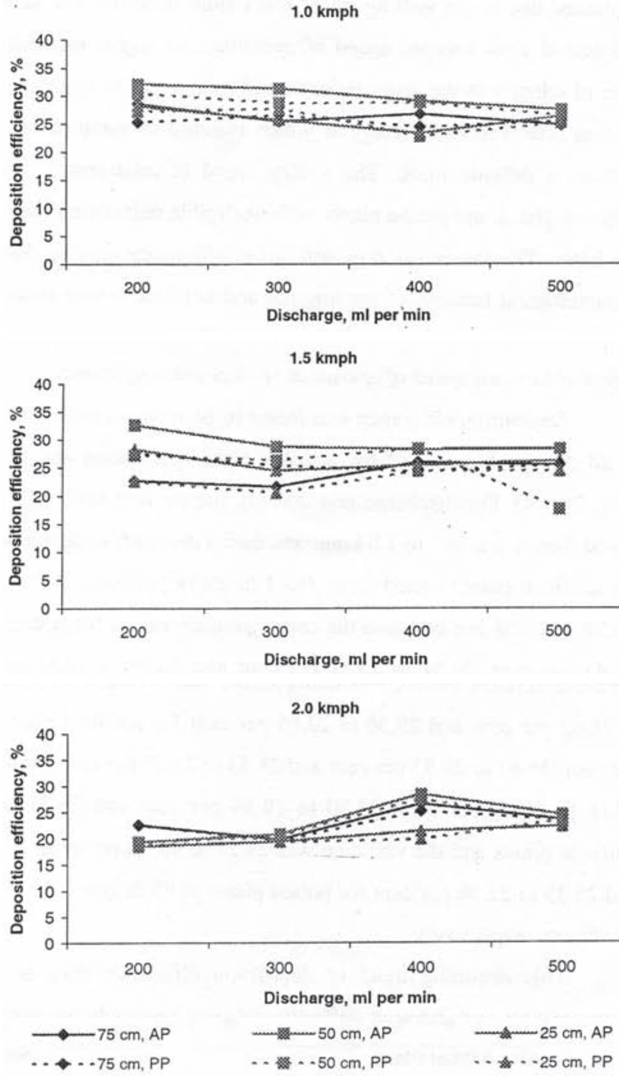
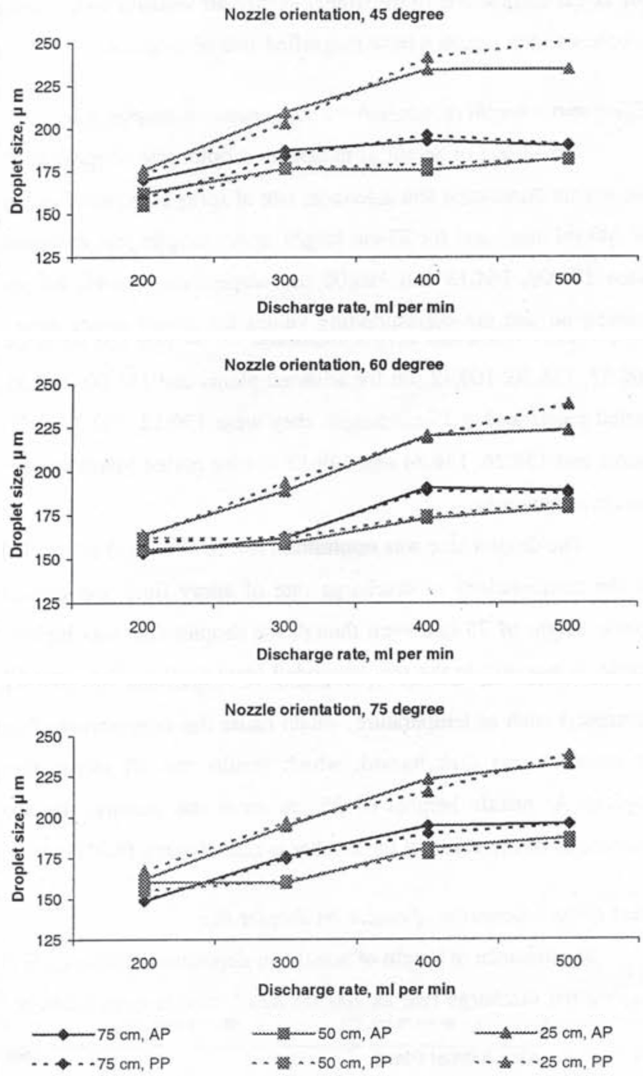


Fig. 5 Effect of spray fluid discharge on drolet size (AP: Artificial poiny, PP: Potted plant)



nozzle height of 25 cm. This tendency may be justified by the lack of sufficient time for the droplets to suspend in the air stream that influence the reorientation of droplets to a spherical shape. Moreover, the splashing of droplets on the target surface due to the higher carrier air velocity would enhance the diameter of droplets and cause a false magnified droplet size.

Effect of Spray Nozzle Height from the Canopy on Droplet Size

The effect of height of nozzle on droplet size for all combinations of the nozzle orientation and discharge rate of spray is depicted in **Fig. 5**. Spray discharge of 200 ml min^{-1} and for 25 cm height, spray droplet size for artificial plants was 176.09, 164.13 and 162.00 µm, respectively, for 45, 60 and 75 degree nozzle orientation and the corresponding values for potted plants were 173.13, 162.74 and 167.49 µm. When the height increased to 50 cm, the corresponding values were 162.55, 155.30, 160.12 µm for artificial plants and 155.00, 162.37 and 155.34 µm for potted plants. At 75 cm height, they were 170.12, 153.33, 148.62 µm for artificial plants and 159.24, 159.74 and 149.12 µm for potted plants, respectively, for the above nozzle orientations.

The droplet size was minimum (150 to 175 µm) at a nozzle height of 50 cm for all the combinations of discharge rate of spray fluid and orientation of nozzle. At nozzle height of 75 cm, even though the droplet size was higher than that at 50 cm height, it was within the recommended level (100 to 200 µm) (Wang et al., 1995). The increment in droplet size could be explained by the effect of extraneous parameters such as temperature, which cause the evaporation of smaller droplets and the more serious drift hazard, which results the off target deposition of smaller droplets. At a nozzle height of 25 cm from the canopy, the size of droplets increased as the discharge rate increased.

Effect of Spray Orientation of Nozzle on Droplet Size

Significance of height of nozzle on deposition efficiency is illustrated in **Fig. 5**. Keeping the discharge rate as 200 ml min^{-1} and nozzle orientation at 45 degrees, droplet size was 170.12, 153.33 and 148.62 µm on artificial plants and 159.24, 159.74 and 149.12 µm on potted plants. However, at 60 degrees, the corresponding values were 162.55, 155.30 and 160.12 µm on artificial plants and 155.00, 162.37 and 155.34 µm on potted plant targets. At 75 degrees these values were 176.09, 164.11, 162.00 µm on artificial plants and 173.13, 162.74 and 167.49 µm on potted plant targets, respectively, for 25, 50 and 75 cm height of nozzles. For all the combinations of discharge rates and heights of nozzles, orientation of nozzle at 60 degrees with the vertical shows the minimum size of droplets. At nozzle orientation of 45 degrees the increment in droplet size could be explained by the splashing of droplets and lack of time to get suspended in air stream. The higher droplet size for the 75 degree nozzle orientation may be due to the evaporation loss and serious drift hazard to the smaller droplets.

Significance of Simulated Artificial Plant

The maximum deposition efficiency was at a discharge rate of 200 ml min^{-1} per nozzle and 1.0 km h^{-1} (application rate 160 l ha^{-1}) at 50 cm nozzle height and 60-degree orientation of nozzle with the vertical for both artificial plant and potted plants. But the interesting feature observed that at the same combinations of height (50 cm above the canopy) and orientation (60 degrees with the vertical) of nozzle and speed of operation (1.5 km h^{-1}) showed the higher deposition efficiency. Moreover, it is clear from the mean of tables 4.2 and 4.4 that the values of deposition efficiency at both the same combinations were on par for all the discharge rates (Walklate et al., 1996). Size of droplets obtained from the laboratory studies also indicated negligible deviation between artificial and potted plants without showing any trend. This substantiates the simulation of the cotton plant with suitable plastic material for the laboratory experiments.

Conclusions

The significance of spray fluid discharge rate, height and orientation of nozzle and operational speed on depositional characteristics of spray and droplet formation was quantified. The deposition efficiency of spray reduced with the increment in discharge rate of spray fluid and forward speed of operation. It was maximum at 50 cm of nozzle height from the canopy and showed a declining trend on both upper and lower heights. The deposition efficiency at a nozzle orientation of 60 degrees with vertical showed the maximum. The maximum deposition efficiency (34.473 %) observed at a fluid discharge rate of 400 ml min^{-1} per nozzle, forward speed of operation of 1.5 km h^{-1}, nozzle height of 50 cm and nozzle orientation of 60 degree with the vertical plane. As the discharge rate increased the droplet size also increased irrespective of height and orientation of nozzle. The size of droplets formed was at the recommended level (100 to 200 µm). The droplet size was minimum (150 to 175 µm) at nozzle height of 50 cm.

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Field Application of Modified Low Cost Dryer for Rice Seed Drying - A Case Study in West Java and Central Java, Indonesia

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Abstract

An overview has been given of the research and development in rice handling and processing that was carried out as a case study at the farmer level in West Java and Central Java, Indonesia. The objective of this research was to improve the efficiency and profitability of rice seed processing. Attempts were made to improve rice seed quality at the farmer level by focusing on the drying with the modified IRRI low cost dryer (LCD). The measurement parameters were moisture content, sound seed, and germination rate. Results indicated that seed drying by LCD had significant quality with normal seedling (95.0-97.0 %), sound seed (98.7-99.4 %) and insect infestation (0-9 %).

Introduction

During the past three to four decades, Asian farmers have dramatically increased rice yields through the adoption of modern rice varieties. During this time, Asian consumers have also become more discriminating in terms of rice quality. Consumers in many countries of the region are now willing to pay a higher price for the specific rice quality that they desire. However, the adoption of modern post harvest technologies and practices that are needed to produce better quality rice has not kept pace with the increased demand for rice with high quality. Inappropriate technologies, unsuitable management techniques and lack of knowledge during grain harvesting, drying, storage and milling often result in quality deterioration and physical losses. Rice quality deterioration can be in the form of high grain breakage, incomplete milling, yellowing or discoloration, impurities or undesirable odors or taste.

Historically, research on rice quality improvement has largely focused on changing quality characteristics by means of genetic improvement and evaluating the effect of component technologies on qualitative changes in the grain.

So far, research on grain quality management throughout the entire post-production system has taken a backseat (Bell et al., 2000). As stated by de Datta (1981) more than two decades ago, attempts that have been made to improve rice processing have often not focused on the total system but have taken a piecemeal approach resulting in little impact on the quality of the rice that arrives at the consumer's table. It was, therefore, important to consider the entire post-production systems and its various players as a system, an approach taken in most temperate-climate rice-growing countries. The objective of the recent research on a component of the rice postproduction system was to evaluate the modified IRRI low cost dryer (LCD), a model dryer with appropriate technology.

Fig. 1 Schematic diagram of heated air flow in low cost dryer

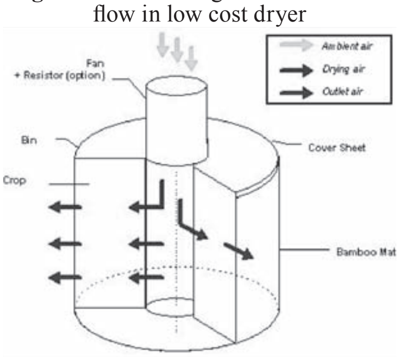
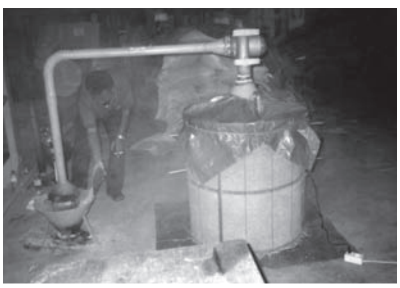


Fig. 2 Low cost dryer testing at farmer site



Research Methods

The LCD with one ton maximum capacity was investigated at a farmer's site who was also a rice seed producer. The characteristics of the modified IRRI-LCD were identified. The standard operational procedure, moisture content, drying rate, air temperature and germination rate were examined during the drying process. The heat source used raw husk and was compared with husk charcoal and husk briquettes. A schematic diagram of the heated airflow in the Low Cost Dryer is shown in **Fig. 1**.

The LCD model dryer (**Fig. 2**) is a multi-crop dryer and can be used for paddy, corn, soybean, and other crops but it has been tested only for rice seed drying. The performance of this dryer is affected by the relative humidity of the ambient air, moisture content of the paddy, and the available electrical power source. This dryer utilizes the principle of a low temperature in-bin drying system and, therefore, cannot dry paddy as fast as sun drying. The dryer itself can serve as temporary storage of paddy after drying.

a. Specifications of the Low Cost Dryer (LCD)

Capacity of the dryer is one ton but adjustable for less quantities. The operator requirements are two persons for loading and unloading. The power requirement is a 0.5 hp, 3450 rpm, 220V, single phase, 60 Hz electric motor. The dryer is 150 cm long, 150 cm wide, 120 cm high with a weight of 25 kg and two 1000 W heating elements 15 cm long. The operational heater management in drying from very wet paddy to normally wet during dry and rainy seasons are shown in **Tables 1** and **2**.

The original LCD seed dryer was made from nylon wire and was not very robust. Loading and unloading paddy damaged the sidewalls and made it difficult to get a central position of the air chamber and keep the outer walls concentric in the shape. The nylon wire mat was replaced by steel matting, which improved rigidity and shape.

Aeration holes in the original husk stove were 5 mm in diameter. This caused problems with combustion. Enlarging the holes to 10 mm in diameter and adding a number of holes in the wall and the bottom of the stove significantly improved the performance.

b. The LCD Capacity

The holding capacity of the LCD is one ton but it can be used for lower capacities by adjusting the circumference of the drying bin (as mention in **Table 3**).

c. Moisture Content

One of the drying conditions mentioned here is the data from the rice seed drying process that began

Table 1 Operational LCD heater management in drying very wet paddy during rainy and sunny days

Heater settings and duration	
Rainy days	Sunny days
Low: 4 hours	Off: 3 hours
Medium: next 4 hours	Medium: 3 hours
Off including blower: 1 hours	Off including blower: 1 hours
Medium: until paddy is dried to desired moisture (normally 14 % MC)	Medium: until paddy is dried to 14 % MC

Table 2 Operational LCD heater management in drying normally wet paddy during rainy and sunny days

Heater settings and duration	
Rainy days	Sunny days
Low: 2 hours	Off: 3 hours
Medium: next 4 hours	Medium: 3 hours
Off including blower: 1 hours	Off including blower: 1 hours
Medium: until paddy is dried to desired moisture (normally 14 % MC)	Medium: until paddy is dried to 14 % MC

Note: Blower must always be on except as specified for tempering purpoes with the initial moisture content at 20.9 % and the drying process was stopped when the grain reached 13 % moisture. The drying process (**Fig. 4**) took 14 hours and the average drying rate was 0.60 %/hr. There were differences in moisture content (moisture gradient) from 0.5-1.8 % between the front side and rear side of grain chamber.

d. Air Temperature and Humidity

The air temperature in the plenum chamber was held at 50 ºC constantly, while the temperature inside the grain chamber varied between 28-32 ºC. The relative humidity of the air was 95-98 %, and the humidity gradually dropped to 44 % after the grain was dry (**Fig. 3**).

e. Germination Rate

The grain dried in the LCD dryer had a germination rate of around 96 % and contained 3 % dormant seed and 1 % dead seed. Drying seed using low temperature (32-44 ºC) resulted in a higher initial level of germination rate that increased even further after the dormancy period (**Table 4**).

f. Fuel Consumption

The LCD used raw husk as the source of heating air. The consumption of raw husk was 105 kg for 1000 kg of rice seed. While the husk was often free at the rice mill, the cost was up to 2.3 US$/ton in more remote areas. Additional heat sources for the LCD were husk briquettes and husk charcoal (**Table 4**) that gave less smoke than raw husk but made the operation cost more.

Conclusion and Suggestion

The low cost dryer had simple construction and an adjustable capacity that enabled it to be applied for both individual and farmer groups especially for rice seed drying. The characteristics of the dryer were influenced by the atmospheric humidity, thus, indoor utilization is suggested.

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Table 3 Determing the LCD capacity

Capacity, kg	Circumference, cm	Bin diameter, cm
1000	450	145
900	430	138
800	411	131
700	396	126
600	361	115
500	333	106

Table 4 Germination kernel against the various biomass fuel rice husk base

Treatment biomass fuel	Moisture content, %	Rough rice, %		Germination kernel, %		
		Good	Empty/ dirty	Normal	Abnormal	Dead/spoil
Raw husk	13.73	94.12	5.88	96.67	2	1.33
Husk briquette	13.77	89.81	10.19	96.67	2.33	1
Husk charcoal	13.57	92.66	7.34	95.33	3.67	1

Fig. 3 Grain moisture changing during drying

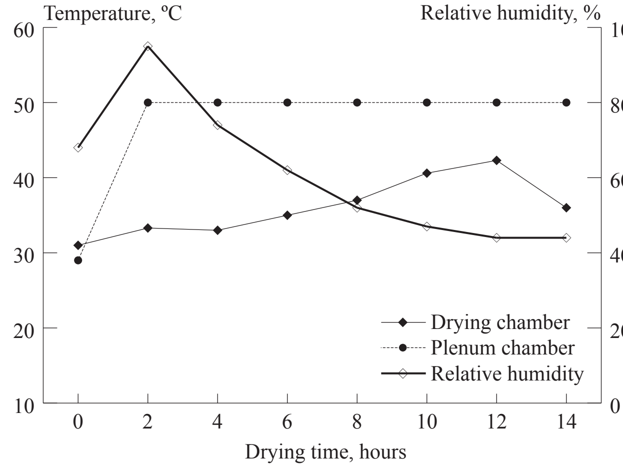
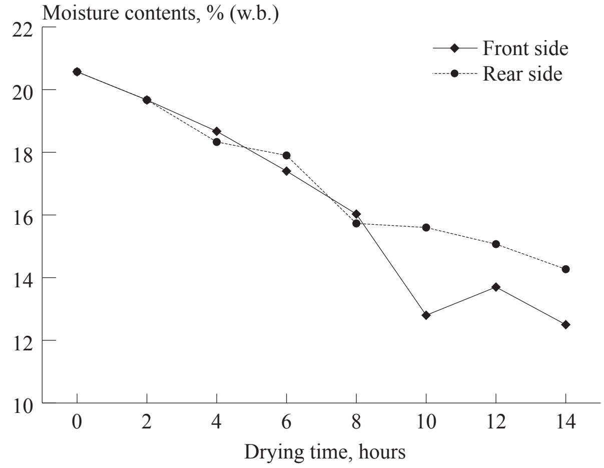


Fig. 4 Average condition at air during drying process



Under and Above Ground Storage Loss of Sorghum Grain in Eastern Hararge, Ethiopia

by

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Abstract

A comparative study was conducted at Alemaya University on the performance of improved above ground storage (Gotera) and underground storage (pit) structures using Randomised Completely Block Design in three replications. Sorghum grain was stored for twenty months using under and above ground structures. Grain temperature, moisture content, germination rate and weight loss were the parameters used to evaluate the storage.

Grain weight loss, moisture content and germination rate in all storage structures were statistically significant ($p < 0.05$). However, a highly significantly, increased temperature, germination rate and weight loss ($p < 0.01$), as well as higher moisture content ($p < 0.05$) were observed in underground storage (pits). This showed that there was a high potential grain loss in pits. Therefore, the underground pit storage structure was not an alternative to the traditional above ground storage. The improved Gotera could be used for small-scale farmers.

Introduction

In East and West Hararge region of Ethiopia, the total grain sorghum (*Sorghum bicolor (L.) Moench*) production in the year 2002 was estimated to be 1.48 million MT and it accounts to about 48 % of the total cereal production (CSA, 2003). In this Region, 75 % of the farmers exclusively use underground storage pits and 25 % use different traditional above ground storage structures for storage of the produce (Lemessa, 1994; Lynch et al., 1986). The traditional underground storage is known to be associated with a number of problems (Boxall, 1974; Niles, 1976).

Postharvest losses of grain in dry and humid parts of Ethiopia are estimated to be 20 % and 50 %, respectively (Hobbs and Zewdu, 1965; Lemessa, 1994; Tadesse et al., 1986). This can be attributed to the unsatisfactory traditional method of grain drying, storage, handling and processing practices that are being utilised almost all over the country. Coupled with lack of and/or limited transportation facilities, this has undoubtedly contributed to the prevailing chronic food shortage of the nation.

Quantitative information on sorghum grain loss when stored using above and underground storage structures is not available in eastern Ethiopia. Such information is essential in order to promote appropriate storage structures for small-scale farmers.

The objective of this study was to determine the extent of loss incurred to sorghum grain stored using Goteras and pits in eastern Ethiopia.

Material and Methods

Construction of Storage Structures

Three Goteras (cribs) with a capacity of 600 kg each were designed and constructed from local materials. Three underground pits with a capacity of 600 kg each were constructed following local farmers' construction method. Both Goteras and pits were established on Alemaya University campus at 1980 masl. The vertical height from top to base and diameter of the Goteras were 200 cm and 75 cm, respectively. The roof of the Goteras were covered by 5 cm thick bundles of grass and then by corrugated metal sheet (**Fig. 1**).

The vertical height of the pits from neck to the base was 225 cm. The neck and base diameter were 50 cm and 150 cm, respectively. Inside walls of the pits were lined with 8 mm polyethylene sheet to protect

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the movement of water (moisture) from the wall of the pit to the stored sorghum grain. The pits were closed by placing logs across the openings and sealed by cementing material prepared from mixtures of cow dung and mud. Finally each pit was covered by 25 cm of soil to above the ground surface level (**Fig. 2**).

Fresh harvested sorghum grain was used. Each above ground (Gotera) and underground (pit) storage structure was filled with about 600 kg of sorghum grain. The experiment had two treatments: Gotera and pit. The treatments were arranged in randomised complete block design (RCBD) with three replications. The grain was stored for 20 months until the experiment was terminated in September 2003.

Sampling Procedures

Sorghum grain samples were collected from each pit and Gotera starting from the first day of storage every two months for a period of 20 months with the help of a two meter long double tier tube sampling probe with six openings of heavy metal point. A grain sample of 2 kg each was taken from the centre, side and bottom of each pit and Gotera. The grain samples were thoroughly mixed in order to get a composite sample. The composite samples were kept in airtight plastic bags for subsequent laboratory analysis. These samples were used for the tests described below.

Measurement of Grain Moisture and Temperature

The grain moisture was determined after collection of samples by digital moisture meter (HOH express HE 50). The temperature was measured in each pit and Gotera with a two meter long digital electronic thermometer attached to HOH express HE 50. Measurements were taken at the top, sides, middle and bottom of each pit and Gotera and the average was recorded.

Germination test

The germination test used 400 grains from each pit and Gotera on each sampling day. The seeds were kept in Petri dishes lined with moist filter paper in three replications and incubated at room temperature for 5 to 8 days.

Weight Loss

The Count-Weigh-Method with the following formula (Salunkhe et al. 1985) was used to determine the weight loss in each pit and Gotera.

Weight loss % =

$$\frac{Unb - BNu}{U \times (Nb + Nu)} \times 100$$

Where,

U: Weight of undamaged grain (g)

Nb: Number of the damaged grain

Nu: Number of the undamaged grain

B: Weight of the damaged grain (g)

Data Analysis

A separate analysis of variance for temperature, moisture, germination rate and weight loss was used for each storage structure using MINITAB statistical software. Means separation was done using LSD. A two way factorial analysis consisting of storage structures and storage duration as main effects was conducted for temperature, moisture, germination and weight loss.

Results and Discussion

Table 1 Analysis of variance for temperature (ºC), moisture (%), germination (%) and weight loss (%)

Sources	Parameters			
	Temperature	Moisture	Germination	Weight loss
Storage structure (SS)	120.528**	22.927**	4,216**	135.48**
Storage duration (SD)	17.203**	7.84**	3,863**	331.4**
SS*SD	2.906	4.76**	693.3**	4.06*
Error	3.285	0.759	65.3	8.65

Table 2 Mean value of temperature (ºC), moisture (%), germination (%) and weight loss (%) across storage structure variance

Storage structure	Parameters			
	Temperature	Moisture	Germination	Weight loss
Gotera	20.55	11.71	83.30	9.75
Pit	23.26	12.89	67.36	12.61
LSD	1.1039**	0.578**	4.92**	1.79**

*, **Mean squares of characters were significant at the probability level of 0.05 and 0.01, respectively

Fig. 1 An improved Gotera for sorghum storage, front view

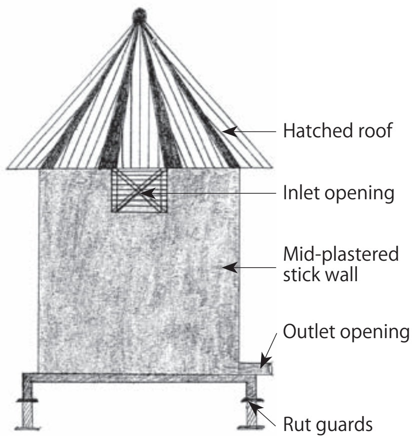
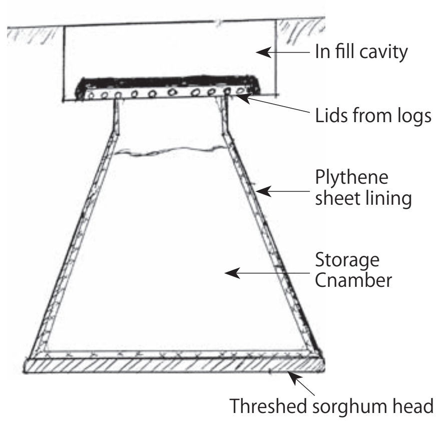


Fig. 2 Cross-section of improved pit for sorghum storage



Conservative estimates report that about 30 to 40 % of crops harvested in the developing countries seldom reach the consumer (Salunkhe et al., 1985). This indicates that supply can be increased by the same amount without substantial expenditure on seeds, fertiliser, irrigation and plant protection measures to produce more crops (Salunkhe et al., 1985). Even though cereal grains are important as food mainly because of their excellent keeping qualities (Adams et al., 1977), they may spoil due to penetration of moisture and storage pests (Gilman, 1968; Kamal, 1980)

Temperature

The average temperature in all storage structures was recorded, as detailed earlier, and analysed. The average temperature ranged from 17.07 ºC to 24.97 ºC in Goteras, and 21.80 ºC to 26.83 ºC in pits (**Table 3**). A combined analysis of variance on storage structures indicated non-significant variation (**Table 1**). However, significant variation was observed in temperature over the duration. The highest temperature in the pit and in the Gotera was at 14 months of storage and was 26.83 ºC in the pit and 24.97 ºC in the Gotera (**Table 3**). Girish (1980) recorded a maximum temperature of 42 ºC in underground pits. The effect of temperature was different between the two storage structures (**Table 3**). The grain in the Gotera remained cooler as compared to the that stored in underground pits.

Moisture

Generally, there was an increase in moisture content as duration of storage increased (**Table 3**). The moisture content of grain in pits was higher as compared to Goteras. There was significant interaction ($p < 0.01$) between storage structure and duration of storage for grain moisture content (**Table 1**). The highest moisture content for the Goteras was 12.47 % at 16 months of storage and for the pits the highest moisture content was 16.37 % at 20 months of storage (**Table 3**). Generally, after 14 months of storage, the grain moisture content of sorghum grain stored in pits appeared to increase. The grain near the side walls of the pits showed a higher moisture content, probably because the grain absorbed moisture from the sidewalls of the pits. The increase in moisture content was reported earlier, either due to attack by insects and micro-organisms (Fekadu et al., 2000 and Kamal, 1980), and/or absorption of moisture by the grain from the wall of the pit. This indicated that the grain stored in the Goteras remained drier as compared to grain stored in pits.

Germination

The sorghum germination decreased as the duration of storage increased in both pit and Gotera. There was significant interaction between storage structures and duration for germination rate (**Table 1**). An average of 83.3 % germination rate was recorded in Gotera, while 67.4 % germination rate was recorded in pit (**Table 3**).

The germination rate reduced as storage time increased in both storage structures with the reduction being greater in pits (**Table 3**). At the end of storage period, 61 % and 3.3 % rates of germination were recorded in Goteras and pits, respectively. The lower germination rate in pits may be due to the destruction of the sorghum grain embryo by storage fungi and insects (Fekadu et al., 2000). As a tradition, farmers of this region do not store sorghum grain used for seed in pits. This might be a result of germination loss for seed stored in pits.

Grain Weight Loss

There was significant interaction for weight loss ($p < 0.01$) between storage structures and storage du-

Table 3 Mean value of temperature (ºC), moisture (%), germination (%) and weight loss (%) from the separate analysis of variance

Duration (month)	Storage structure							
	Gotera				Pit			
	Temperature	Moisture	Germination	Weight loss	Temperature	Moisture	Germination	Weight loss
0	20.13	11.43	98.67	0.40	22.43	11.23	98.67	0.40
2	19.90	11.10	96.67	2.27	22.53	10.87	96.00	3.97
4	17.90	11.20	95.33	4.80	23.27	11.47	94.67	5.77
6	21.70	11.57	92.00	6.16	22.67	11.47	94.00	8.13
8	19.33	11.43	86.33	9.23	21.80	12.17	86.33	7.01
10	20.27	11.93	91.00	14.32	22.60	11.73	85.33	12.13
12	17.07	11.90	90.00	9.57	21.97	11.97	83.00	13.60
14	24.97	11.60	82.67	12.54	26.83	14.77	60.00	15.25
16	21.93	12.47	69.00	10.51	22.90	13.57	24.00	16.78
18	21.30	11.87	54.17	18.43	24.60	16.13	15.67	28.83
20	21.57	12.27	61.00	18.97	24.20	16.37	3.33	26.87
Mean	20.55	11.71	83.35	9.75	23.26	12.89	67.36	12.61
LSD	2.63	NS	10.83	4.50	1.47	1.42	9.95	3.38

*, **Mean values squares of characters were significant at the probability level of 0.05 and 0.01, respectively ration (**Table 1**) and there was a higher weight loss in pits than in Goteras. The greater weight loss in pits may have been due to high moisture content and temperature, which favoured the growth of insects and pests. Grain in the pit was not used for seed since the viability was reduced.

Conclusions

On the bases of the results obtained from the current study, grain stored in pits had a high weight loss and low viability as well as an increment in temperature and moisture content. This indicates that grain can be stored relatively longer period and be in better condition in Goteras than in pits in eastern Ethiopia. Therefore, the underground storage pit structure is not an alternative to the traditional above ground storage (Gotera). The improved Gotera lined with polythene sheet can be used for small-scale farmers. Small-scale farmers can purchase the polythene sheet from the local market for a reasonable price. The polythene sheet also waterproofs the inner walls of the Gotera. Further, pest infestation in the Gotera can be better controlled with proper fumigation.

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Field Evaluation of Power Weeder for Rain-fed Crops in Kashmir Valley

by

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Abstract

Weeding is essential to improve productivity of field crops. Manual weeding by using the Tangroo (local tool) is the most common practice in the cereal and vegetable crops adopted by the farmers of the Kashmir valley. Suitable mechanization technology is needed to reduce drudgery and enhance timeliness of operation. The TNAU power weeder was tested for its feasibility in the valley lands. The time input for the power weeder was about 157 h/ha less than the Tangroo (local tool). The power weeder had the lowest weeding time (10 h/ha), maximum coverage area (0.1 ha/h) and a higher yield (13 %) over traditional practice. The power weeder reported 65-78 % weeding efficiency, depending upon the types of crop, with cost of operation of Rs. 758/ha. The higher crop yield for the power weeder clearly indicated the importance of proper weeding and timely weeding as a substantial yield increase.

Introduction

Weeding is one of the most important labour consuming operations. Manual weeding with the Tangroo (local tool) is the most common practice in the cereal and vegetable crops adopted by the farmers of the Kashmir valley. In orchards, weeding operation is not possible with the manual weeder within the available period of time. Also, manual weeding leads to labour scarcity and increased cost. Recently there is a rising awareness among the farmers for the need to mechanize this operation because of the severe scarcity in labour. It is estimated that at least 20 % yield is lost annually due to improper weeding (Biswas, 1991). Hand tools (khurpi, hoe) require 300 to 500 man-h/ha depending upon the weed infestation (Guruswamy et al., 1991). Thus, traditional methods of weed control give low output resulting in delayed weeding with high cost. Various types of improved manual weeders have been developed in the country, but performance of the power weeder has so far not been evaluated in Kashmir Valley. In order to assess the possibility of mechanization of the weeding operation, a TNAU Power Weeder was tested for its performance in the valley lands and was compared with the wheel hand hoe and manual weeding method existing in the region.

Materials and Methods

The power weeder developed at TNAU was tested for performance in the valley lands at University farm and farmers' field in apple, pear, maize and rajmash crops during the year 2004-05. A photograph of the power weeder is shown in **Fig 1**. The results were compared with wheel hand hoe and manual weeding using the Tangroo (local tool). The experiments used a plot size of 20 x 20 m in RBD configuration with three replications. The yield data of maize and rajmash crops was also recorded along with other machine parameters. The cost of operation was based on the prevailing market rates during the season. The power weeder was fitted with a 8.38 hp high seed automotive diesel engine. It consisted of a rotovator with a multi-edged rotary cultivating device. The rotovator depth was controlled by adjustment of tail-wheel assembly. In order to form ridges and furrows and earthing up operations, an adjustable ridger was also provided as an attachment to a common shank of the power tiller. It consisted of a shank, tail board and

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adjustable mould boards. The mould board could be adjusted to obtain a furrow width of 180 to 360 mm. The detailed specifications of the power weeder are given in **Table 1**.

The functional and economical aspects of the power weeder were tested with respect to the following;

- Extent of achieving timeliness of operation and contribution of the equipment in enhancing the productivity
- Improvement in quality of work
- Reduction in drudgery
- Improvement in safety
- Cost effectiveness

Suitability of the equipment to the region with respect to the following;

- Crops grown
- Problems existing in conventional practice
- Prevalent farm power sources
- Socio-economic factors
- Labour scarcity in the season
- Hiring charge
- Initial cost of the machine
- Operational skills required
- Repair and maintenance facilities

Fig. 1 TNAU power weeder

Results and Discussion

Table 2 shows the field performance of the TNAU power weeder along with the PAU wheel hand hoe and manual weeding. A maximum width of cut of 47 cm was obtained for the power weeder followed by 9 cm for the wheel hand hoe. The manual weeding with the Tangroo had a minimum width of cut (7 cm). The penetration in the soil was maximum (5 cm) for the power weeder compared to the wheel hand hoe (2-3 cm).

Manual weeding with the Tangroo had a minimum depth of cut of 1.2 cm). The speed of operation was almost equal to the power weeder and wheel hand hoe under actual field conditions (1.9-2.0 km/h). The manual weeding with the Tangroo operated at the lowest speed of operation was 1 km/h. The highest field capacity and field efficiency (0.1 ha/h and 67 %) was recorded for the power weeder followed by the wheel hand hoe (0.02 ha/h and 62 %). Singhal (1998) reported that the wheel hoe can cover about 0.2 ha/day during weeding.

The Tangroo (local tool) recorded the lowest field efficiency of 31 % possibly because, during weeding, repeated push and pull action was

Table 2 Performance of power weeder in comparison to wheel hand hoe and Tangroo (local tool) in maize and rajmash

Parameters	Observed value		
	Power weeder	Wheel hand hoe	Tangroo (local tool)
Row to row spacing, cm	40	40	40
Plant to plant spacing, cm	20	20	20
Av. soil M.C., %	18.5-21	18.5-21	18.5-21
Bulk density of soil, g/cc			
Before use	1.29	1.29	1.29
After use	1.23	1.25	1.27
Operational speed, km/h	1.9	2.0	1.0
Fuel consumption, lit/h	1.2	-	-
Working width, cm	47	9.0	7.0
Av. depth of tilled soil, cm	5	3.0	2.2
Plant damaged, %	5	Nil	Nil
Weeding efficiency, %	65-78	55-60	90.0
Effective field capacity, ha/h	0.1	0.02	0.006
Field efficiency, %	67	62-64	31
Labour requirement, man-h/ha	10	100-112	167
Cost of operation, Rs./ha	782	417*	1,252*

*Labour charges = @ Rs.60/day for 8 hr

Table 1 Specifications of the power weeder

Particulars	Specification	Particulars	Specification
Make	TNAU	Gear box	6 forward and 2 reverse
Engine		Turning clutch	Dog clutch
Power	0.38 hp ELGI diesel engine (rope start)	Rotavator	
Fuel Consumption	0.75 to 1.0 litre/hr	Diameter	425 mm
Fuel tank capacity	5.50 litres	No. of blade	24
Overall dimensions		Shape of blade	Backward curved - tip twist blade
Length	1675 mm	Width	475 mm
Width	530 mm	Ridger	
Height	1065 mm	Length	500 mm
Weight	230 kg	Width	490 mm
Transmission		Height	340 mm
Main clutch	Multi plate dry type	Weight	14 kg

required like a spade causing excessive fatigue to the operator. Although the Tangroo (local tool) reported 90 % weeding efficiency, the cost of operation was the highest (Rs. 1252/ha). On the other hand, the power weeder reported 65-78 % weeding efficiency depending upon the types of crops with a cost of operation of Rs. 758/ha. The wheel hand hoe reported 55-60 % weeding efficiency with the lowest cost of operation (Rs. 417/ha). The labour requirement was lowest for the power weeder (10 man-h/ha) in comparison to the wheel hand hoe (100-112 man-h/ha) and Tangroo (167 man-h/ha). The power weeder and wheel hand hoe also caused less fatigue to the operator. Guruswamy (1986) reported that the khurpi for weeding demands 300-500 man-h/ha depending upon weed infestation. This showed that weeding was a labour intensive and tiresome operation. Farmers in the valley generally avoided this important operation due to unavailability of an improved weeder and scarcity of labour. The damage to the plants was a maximum of 5 % for the power weeder in maize and rajmash crops, while plant damage was observed almost nil with the wheel hand hoe and Tangroo (local tool).

Yield data and time taken to complete the weeding operation using different weeding equipment/tools is given in **Table 3**. The average yield of maize crop varied from 17 to 20 q/ha, while in the rajmash crop it varied from 5.9 to 6.30 q/ha depending upon the weeding equipment used. The corresponding time of weeding ranged from 10 to 167 h/ha. Weeding with the power weeder showed the highest maize crop yield (20.05 q/ha) due to mixing of weeds in the soil by the rotation of the tynes followed by wheel hand hoe (18.90 q/ha). The human hours input for these two weeding operations were 10 h/ha and 106 h/ha, respectively. Obviously, the power weeder had the highest maize and rajmash crop yields of 20.05 and 6.30 q/ha, respectively, while utilizing 157 h/ha and 96 h/ha less human time than the Tangroo (local tool) and wheel hand hoe. The higher crop yield for the power weeder clearly indicated the importance of proper weeding and timely weeding as a substantial yield increase. A number of studies conducted in various parts of the country (Verma and Singh, 1994) indicated that land productivity can be increased by 10-15 % by timely intercultural operation.

Conclusion

It is inferred that weeding is an important operation for field crops and if done properly with efficient, high output, low cost and easy to operate weeding equipment, a significant yield increase could be achieved. From the above studies it is concluded that the TNAU Power Weeder is an efficient and most promising weeding machine for medium and large farmers. The feedback regarding the TNAU power weeder are given below:

- The diesel engine is difficult to start in winter season.
- The initial cost of power weeder is high.
- There is a lack of service, repair and maintenance facilities in the near by area.
- The cost of weeding is reduced.
- The labor required for weeding can be reduced.
- No supervision job is required.
- Ten man-hr are required to cover one-hectare area as compared to167 man-hr for weeding one hectare by conventional practice for orchards and maize crops.
- Frequent cleaning of weeds wound over the rotary tyne is required.
- Weeds are cut in pieces and mixed with soil; it helps to enhance the organic manure value of the soil.
- Bending posture adopted in the conventional method is eliminated by the use of weeder. Hence, from an ergonomic point of view, the workers will be relieved of back problems.

Table 3 Experiments on weed management using different weeders in maize and rajmash

Treatment	Maize		Rajmash		Mean time taken, h/ha
	Av. yield, q/ha	Time taken, h/ha	Av. yield, q/ha	Time taken, h/ha	
Tangroo (local tool)	17.30	158.4	5.90	175.6	167.00
Wheel hand hoe	18.90	104.6	5.95	107.6	106.00
Power weeder	20.05	8.5	6.30	11.5	10

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Fig. 2 Power weeder in operation in maize crop

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(Continued from page80)

AThe Farm Machinery Industry in Japan and research Activities: The Present State of Farm Machinery Industry

over the preceding year.

Major imported farm machines: tractor 1,541 units (those more than 70 PS were 1,297 units of all the tractor); chain saw 61,094 units, lawn mower 332,619 units, mower 105,582 units, fertilizer distributor 2,244 units. Tractors 441 units were imported from France, and 290 units from Italy, 258 from U.K., 154 from German, 114 from Finland.

Trend of Research and Experiment

The surroundings of Japanese agriculture are very hard, because of increased imported agricultural products, consumer's various favor, the decrease of the new farmers, being called for the contribution to solve the environmental problems. That's why the structural and technical reforms in Japanese agriculture are required urgently.

The government issued "Basic Research Plan for Agriculture, Forestry and Fisheries" in March, 2005 to set the objectives of the development in the future ten years . In the field of next generation farm mechanization technology development,

It is encouraged to develop "high performance production control system with IT technology", "labor and energy saving, safe production system utilizing automation technology" and etc.

Research results of farm mechanization by National Agriculture and Food Research Organization in 2006 were;

- Tractor driving instruction device to minimize fuel consumption and black gas emission
- Technology to reduce harvest loss of soybean combine
- Potato foliage and haulm cleaner
- Self-propelled chopping harvester for forage rice
- Ripple cleaning device with bacillus removing effect
- Tractor guidance system displaying driving route
- Program to send cropping condition and yield information from machine to mobile monitor .

■■

Ergonomic Studies on the Location and Operational Frequency of Controls in Indian Farm Tractors

by
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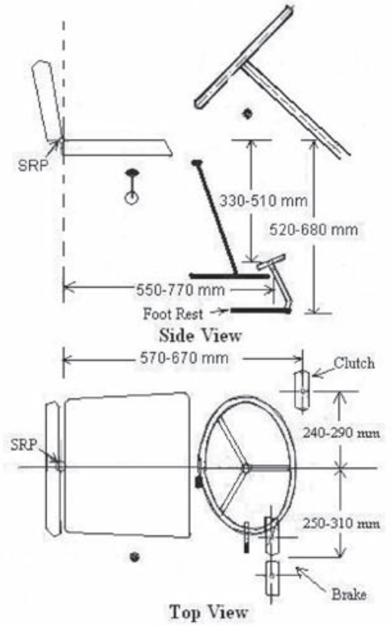
Abstract

This study was conducted to observe the existing location of controls like brake pedal, clutch pedal, hydraulic control lever, hand accelerator, foot rest and gear lever in selected farm tractors and the frequency of operation of these controls while doing field operations with different farm implements. The parameters measured were forward horizontal distance, vertical distance and lateral horizontal distance from SRP. The orientation of steering and operators seat in the workspace of a tractor was also studied using an anthrometric apparatus. There was large variation in the location of controls for different tractors. The frequency of viewing backward was also observed and was 32-62, 50-75, 22-62 and 13-19 for Mould Board Plough, Disc Plough, Disc Harrow and Tiller, respectively. Also, the frequency of viewing backward was more than the frequencies of operating the clutch, brake and hydraulic control lever.

Fig. 1 Horizontal, vertical and lateral distances of brake pedal, clutch pedal and foot rest from SRP



Introduction

Mechanization brought an outstanding development in Indian agriculture where agricultural tractors played an important role. Tractors came into existence about a century ago but gained popularity during World War I & II because of the enormous increase in demand for food and fibre with less available agricultural labour. In India, tractors had been introduced during the seventies (1970-71). Evolution of tractors has accompanied changes in farm technology. Depending upon local and domestic conditions, various types and sizes of tractors have been developed and used worldwide. The tractor has progressed from its original primary use as a substitute for animal power to present units designed for multiple uses. Traction power, belt power, PTO mounted tools, hydraulic control unit, climate controlled cabs and power steering all serve to extend the usefulness and efficiency of modern tractors. The design of modern tractor includes consideration of human factors because the ultimate objective of ergonomic studies is to optimize the man-machine-environment system to harness greater system efficiency. A tractor operator sits on the seat and operates various controls and monitors the operations. The dimensions of the seat and location of controls are useful in designing the tractor work place. Location of controls should be such that they are easily accessible to the operator. If the operator's controls are not properly adopted to his anatomy, the required performance can not be achieved. Thus, the possibility of accidents are also increased. So, a study was planned to identify existing location of controls in selected Indian farm tractors and also the frequency of operations of various controls.

Review of Literature

The location of various controls was one of the major objectives of the ergonomic studies and the following reviews have been cited for this study.

Dupius (1950) used respiratory and heart rate as measure of load in the study of tractor driving and work with implements. The controls and seats in different orientation were also studied to evaluate optimum configuration involving minimum operator stress.

Woodson (1973) studied location of the foot pedal with respect to seat reference point. According to him, location of control should provide comfort to the operator. The pedal should support the foot comfortably. For shifting the foot from one pedal to another there should be sufficient clearance provided. Also, there are chances of the foot slipping from the pedal while operating. To avoid this, the pedal should be provided with a tread. The foot pedal should be large enough to support foot comfortably.

Schrottmair (1982) conducted a survey of 64 different types of machines to obtain data on control requirements. The study revealed that most of the controls must be operated from the tractor seat. Problems arising from operation of tractor mounted equipment were also studied.

Sjoflot (1982) studied the frequency of the operator looking backwards. He concluded that, while working with farm tractor, the operator must spend a large proportion of his time looking backwards and adopting poor working posture. Besides the adverse effect on health and general feeling of discomfort, this bad working posture also affects the quality of work. So a rear view mirror was recommended.

Madan et al. (2002) observed the various horizontal and vertical distances of various controls of the tractor from SRP of tractor. The force acting on the clutch pedal while operating various implements, e.g. Mould Board Plough, Disc Plough, Disc Harrow and Cultivator was found and it was maximum (212 N) when operating a Mould Board Plough and least (202.37 N) for the Disc Plough. Heart rate of the subjects while operating various controls of implements ranged between 86.30 and 98.60 beats per minute.

Material and Methods

Five most popular tractors models, designated as T_1, T_2, T_3, T_4 and T_5, were selected for this study. All these tractors were in the horsepower range of 35 to 50 hp, which was the most popular range being used by farmers in the northern region.

Controls Layout

There are a number of controls located in the workspace of the tractor. Workspace parameters were required to be measured from the design and comfort point of view. These parameters included forward horizontal distance, vertical distance and lateral horizontal distance from seat reference point (SRP) for brake, clutch and hydraulic control lever. Along with these, steering wheel geometry, seat and footrest were considered. For steering, the wheel diameter, the steering column angle and the steering wheel angle with horizontal were measured. Similarly, forward horizontal distance of steering wheel and its vertical distance from SRP and height of SRP above the footrest were considered. Seat specification measurement included seat depth, backrest width, backrest height, backrest inclination and seat surface inclination. Seat adjustment range in both horizontal and vertical direction was also taken into account. An anthropometer instrument was used to measure these parameters.

Frequency Recording of Control Operation

Frequency of operation of various controls while performing field operations for 15 minutes with different tractor mounted implements was measured. Controls of the tractor to be studied included clutch, brake, hand accelerator and gear shift lever. It was very important from orientation point of view to study the frequency of these controls so that the appropriate location of the control in the workspace could be determined for reduced efforts of the operator.

Implements Under Study

The frequency of the operation of different controls and viewing backward while doing various till-

Fig. 2 Horizontal, vertical and lateral distances of hydraulic control lever (Draft control and position control) and gear lever from SRP

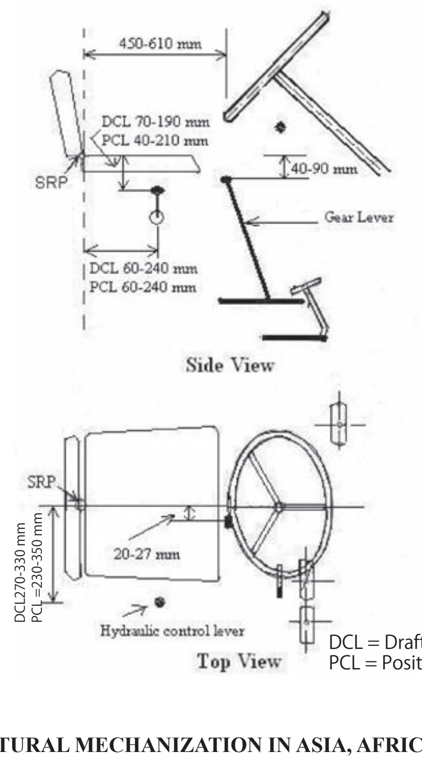
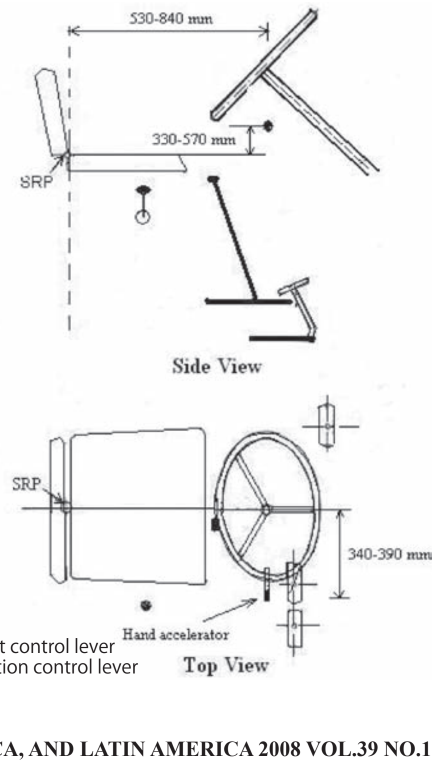


Fig. 3 Horizontal, vertical and lateral distances of hand accelerator



age operations with commonly used implements, was observed. Land preparation implements selected for this study were mould board plough, disc plough, disc harrow and tiller.

Methodology

The horizontal, vertical and lateral distances of the various controls were measured using the anthropometer with the SRP as the base point in the stationary condition with the tractor on level ground.

The frequency of use of various controls viz., clutch, brake, hand accelerator and gear, was observed. The frequency of use of various controls by the operators i.e., S_1, S_2 and S_3, was observed during the field operation for 15 minutes with the implements under study until the operation was completed. The frequency of viewing backward by the operator was also observed.

Results and Discussions

The results of the study of the location of controls on different tractors, orientation of steering, operator's seat in workspace and frequency of operation of various controls for different farm implements have been presented and discussed below.

Brake and Clutch Pedal

Horizontal forward distance of brake pedal from SRP in all tractor models viz., T_1, T_2, T_3, T_4 and T_5, were in the range of 550 to 770 mm with an average distance of 662 mm (**Fig. 1**). For the clutch pedal, this distance was 570 to 670 mm with an average of 640 mm. The vertical distance of brake and clutch pedal from SRP was in the range of 330 to 510 mm and 330 to 480 mm, respectively. The lateral distance for brake and clutch pedal varied from 250 to 310 mm and 240 to 290 mm, respectively.

Hydraulic Control Lever and Foot Rest

The forward horizontal distance of the draft control lever was in the range of 60 to 240 mm (**Fig. 2**). The vertical distance was in the range of 70 to 190 mm, whereas lateral distance was in the range of 270 to 330 mm. Variation was more in horizontal and vertical distance and very small in lateral distance.

Forward horizontal distance varied from 60 to 240 mm for position control lever, (**Fig. 2**). Vertical and lateral distances fell in the range of 40 to 210 mm and 230 to 350 mm, respectively. Both draft and position control lever were located at almost equal forward horizontal, vertical and lateral distance from SRP. The footrest height below SRP showed little variation. It ranged from 520 to 680 mm for all selected farm tractors (**Fig. 1**).

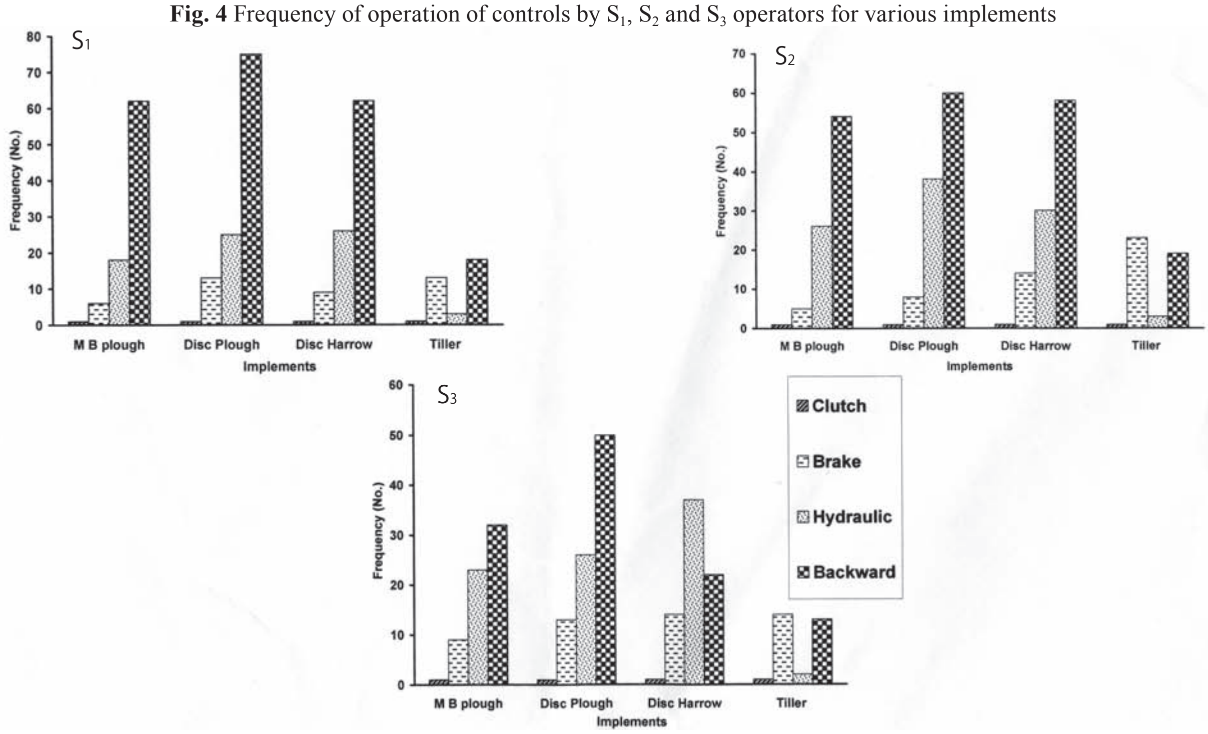
Gear Lever

Locations of gear levers for different selected tractors are indicated in (**Fig. 2**). Range for forward horizontal distance, vertical distance and lateral horizontal distance was 450 to 610 mm, 40 to 90 mm and 20 to 27 mm, respectively. In some of tractors, the gear lever was found in line with the seat reference point. Thus, the lateral horizontal distance of the gear lever from SRP in these tractors was zero.

Hand Accelerator

Large variation was observed in

Fig. 4 Frequency of operation of controls by S_1, S_2 and S_3 operators for various implements



horizontal and vertical distances of hand accelerator from SRP (**Fig. 3**). The forward horizontal distance varied from 530 to 840 mm and vertical distance varied from 330 to 570 mm. Lateral horizontal distance was in the range of 340 to 390 mm.

Orientation of Steering in the Tractor Workspace

Steering diameter and rim diameter were almost the same in all tractors studied viz., T_1, T_2, T_3, T_4 and T_5. This variation was between 410 to 450 mm and 25 to 30 mm, respectively (**Table 1**). Average values of steering wheel diameter and rim diameter were 440 and 25 mm, respectively. There was large variation in wheel angle with horizontal (20º to 40º) and steering column angle with horizontal (57º to 80º). Variation in vertical distance of the front edge of the steering wheel was between 90 to 250 mm with an average value of 150 mm. Little variation was observed in horizontal distance of the front edge from SRP (370 to 440 mm with a mean value of 400 mm).

Operators Seat in the Workspace

Non-uniformity exists in design of seat for the operator. Seat width range varied from 375 to 480 mm. Seat depth was between 40 to 160 mm. Backrest width and height varied from 350 to 480 mm and 260 to 320 mm, respectively. There was almost no difference in backrest inclination. It was around 100 in most of the tractors (**Table 2**).

The operator's seat was found to be adjustable both in horizontally forward and vertical direction for all tractors to accommodate 95 percentile of operators. The variation in adjustment range was little. Adjustment range in horizontal direction varied from 60 to 80 mm. Adjustable range in the vertical direction was the same, 40 mm in all tractors.

Frequency of Operation of Various Controls for Different Farm Implements

The average frequency of operation of clutch pedal for M B plough, Disc plough, Disc harrow and Tiller was the same (**Fig. 4**). Clutch pedal was operated only once for all the operations whereas the average frequency of operation of the brake pedal for 15 minutes interval was 9, 13, 14 and 14, respectively, for above mentioned implements. Frequencies for hydraulic control lever operation for different operators was in the range of 18-26, 25-38, 26-37 and 2-3, respectively. Frequency of viewing backwards was 32-62, 50-75, 22-62 and 13-19, respectively, for the different operations for the three subjects. The Disc plough required most frequent operations of almost all the controls. Frequency of viewing backwards was more than frequency of clutch, brake or hydraulic lever operations.

Table 1 Steering wheel orientation in various tractor models

Steering specification	Tractor models (T_1, T_2, T_3, T_4 and T_5)		
	Min.	Max.	Grand Av.
Wheel diameter, mm	410	450	440
Rim diameter, mm	25	30	25
Wheel angle with horizontal, degree	20	40	28
Steering column angle with horizontal, degree	57	80	66
Horizontal distance of front edge of steering wheel from SRP, mm	370	440	400
Vertical distance of front edge from SRP, mm	90	280	150

Table 2 Seat orientation in various tractor models

Steering specification	Tractor models (T_1, T_2, T_3, T_4 and T_5)		
	Min.	Max.	Grand Av.
Seat width, mm	375	480	430
Seat depth, mm	40	160	80
Backrest width, mm	350	480	320
Backrest height, mm	20	320	300
Backrest inclination, degree	7	10	11
Adjustment range, mm			
a. Horizontal direction	60	80	73
b. Vertical direction	40	40	40

Conclusions

The conclusions made from this study were that the locations of main controls, such as clutch, brake, hydraulic control lever in the workspace of tractor, varied widely in the different models of Indian tractors studied. The frequency of viewing backwards was more than the frequencies of operation of clutch, brake and hydraulic control lever.

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Performance of the Ram Press with Different Oilseeds

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Abstract

The ram press is a hand-operated machine used for processing oilseeds in rural areas of Kenya. Tests were carried out to determine its extraction efficiency with different oilseeds with a view to improving its performance. The maximum extraction efficiencies achieved with sunflower, sesame, rapeseed, shelled and unshelled groundnut were 65.79 %, 48.36 %, 55.66 %, 50.9 % and 79.82 %, respectively. No oil was obtained from soybean and only negligible quantities from the local sunflower varieties, Kenya fedha and Kenya shaba. The oil contents for the seeds were significantly different at the 0.05 level. Extraction efficiencies achieved with various seeds, at different choke openings were significant at 0.05 level. The results implied that, to achieve high extraction efficiency, it was necessary for the oilseed to have a balance between oil and fiber contents.

Introduction

The ram press is a manual device used to extract oil from oilseeds such as sunflower, sesame, groundnut and rapeseed. During the oil extraction operation, a small quantity of seed, 20-40 g, depending on the type of seed and ram press, is admitted into the cylinder on the upward stroke. On the down stroke, this quantity of seed is pushed into the cage by the piston where it is crushed against the previously crushed seed and oil is extracted. The oil flows out through small openings, of about 0.8 mm, between the steel bars that make-up the cage.

The performance of the ram press is generally reported in terms of extraction efficiency (EE), which is the percent of the extracted oil over the seed oil content (Kamau, 1990; Simalenga, 1992). Several factors that affect the performance of the ram press include the moisture content, oil content, type and variety of the oilseed and the percent foreign materials. Others are the setting of the choke on the ram press and speed of operation in terms of number of strokes per minute. It is necessary to specify the levels of these factors in order to have useful information on the performance of the ram press. Work reported by several authors cover either one type of seed (Bielenberg, 1996) or specifies a few of the factors (Henriksson, 1994; Kamau, 1990).

Varietal differences that are of importance are oil content and the size and hardness of the husk. An example of this type of difference was observed in sunflower varieties grown in Kenya. The local varieties, Kenya shaba and Kenya fedha have thick hard husks while hybrid varieties such as 98894 have a thin soft husk. In addition, the oil content of the hybrids average above 38 % while the local varieties average around 33 % (Riungu, Thagana and Wasike, 2001). The effect that these differences may have on the performance of the ram press has not been determined.

The amount of pressure that is applied to the seed depends on the position of the choke (also called end plug), which can be screwed in or out, varying the opening between it and the cage. This opening regulates the quantity of seed cake being discharged during each stroke of ram press operation (Appropriate Technology for Enterprise Creation (ApproTec) 1998). The size of the opening determines the pressure that is generated in the cage and applied to the seed. During operation, a range of choke openings are likely to be used as the "best" position is determined subjectively, since, to a great extent, it depends on the ability of the operator to work with the manual ram press. Therefore, it is difficult to locate one single position of the choke opening that is likely to give maximum oil recovery. This necessitated the use of a range of choke openings in order to achieve an unbiased comparison of the performance of ram press with different oilseeds. Reports by ATI T-PRESS (1996) and ApproTec (1998) give different values of EE for sunflower seed. However, these were reported as single values and the possible influence of the choke setting was not incorporated. This study compared the performance of the ram press set at nine choke positions when processing five different oilseeds.

Materials and Methods

A Jaimen ram press (Jaimen, 1990) was used to process sunflower, sesame, soybean, rapeseed, shelled and unshelled groundnut. Three varieties of sunflower seed used were hybrid 98894 and two open-pollinated local varieties, Kenya fedha and Kenya shaba. Sesame used was the white variety, rapeseed was nyala variety, groundnut was the small red variety and soybean was the line variety. Fifty kg of each type of seed was obtained and, where necessary, dried to storage moisture content of about 6-8 %, on the wet basis. The seeds were cleaned with a fanning mill then characterized by determining their moisture content, oil content, bulk density, percent foreign materials and the kernel to husk ratio for sunflower and unshelled groundnut.

Moisture content was determined by drying ground samples in an air oven set at 103 ºC for 2.5 hours (Kamau, 2002). Foreign matter in the seed was determined by placing a 250 g sample at the top of a set of sieves, which were then shaken using a Ro-Tap Shaker machine for five minutes. Materials equal in size to or larger than the seed were picked by hand. Oil content was determined by the Soxhlet method using petroleum ether (Paquot and Hautfenne, 1987). Bulk density was determined by weighing a sample of seed in a one-liter container. The ratio of kernel to husk by weight was determined by shelling 100 g of seed by hand. This was followed by experiments to determine oil recovery at different choke positions for each type of seed. Choke opening was measured in terms of the size of the gap between the choke and the cage in mm. The nine choke positions, from nearly closed to fully open, were 10.8, 11.4, 11.8, 12.3, 12.8, 13.1, 13.3 and 13.8 mm. Two kg of seed were first processed to get the material moving steadily through the press before the choke was adjusted to the desired position. One kg of seed was processed at each position. The recovered oil was first passed through a tea strainer to remove particles before it was weighed. The cage was cleaned thoroughly before changing from one type of seed to another.

Results and Discussion

The mean values of oil content, moisture content, bulk density and mass of kernel and husk are shown in **Table 1**. Sesame seed had the highest oil content at 48.94 % while soybean had the lowest at 18.57 %. The husk to kernel ratio (h/k) for groundnut was relatively high at 27.43 % which made the oil content of the unshelled groundnut appear low at 29.65 %. Bulk density for rapeseed was highest at 641.25 kg/m^3 followed by sesame at 604.43 kg/m^3 and was lowest for unshelled groundnut at 251.15 kg/m^3. The higher bulk density reflected a lower husk to kernel ratio for the seed and therefore a lower fiber content.

Mean values of oil recovered in g per kg of seed for the different seeds are shown in **Table 2**. No oil was recovered from soybean while only negligible quantities were obtained from the local sunflower varieties, Kenya fedha and Kenya shaba. At a choke position of 10.8 mm, the cage opening was nearly closed and

Table 1 Seed characteristation data

Type of seed	Moisture content[1], %	Foreign matter, %	Oil content, %	Husk/ kernel ratio	Bulk density, %
Sunflower hybrid 98894	8.74	2.13	39.52	5.46	365.54
Sunflower Kenya *Fedha*[2]	3.93	2.48	26.98	18.67	341.22
Sunflower Kenya *Shaba*[2]	4.73	1.74	25.18	21.66	348.79
Sesame	6.14	1.83	48.94	-	604.42
Groundnut (shelled)	7.75[3]	0.53	45.82	-	560.76
Groundnut (unshelled)	6.34[3]	0	29.65	27.43	251.15
Rapeseed	3.04	0.45	41.92	-	641.26
Soybean	10.51	0.84	18.57	-	548.27

[1]Moisture content on the basis, [2]Local open-polinated varieties, [3]After drying

Table 2 Oil recovered at different choke opening

Choke opening, mm	Oil recovery, g per kg seed						
	Sunflower hybrid 98894	Sunflower Kenya *Shaba*	Sunflower Kenya *Fedha*	Sesame	Rapeseed	Groundnut (shelled)	Groundnut (unshelled)
10.8	0	0	0	0	0	0	0
11.4	0.21	0.02	0.037	0.17	0.1	0.15	0.2
11.8	0.23	0.03	0.047	0.22	0.18	0.21	0.24
12.3	0.25	0.07	0.083	0.23	0.23	0.23	0.24
12.8	0.22	0.03	0.03	0.24	0.21	0.22	0.21
13.1	0.19	0	0	0.22	0.19	0.18	0.18
13.3	0	0	0	0.19	0.15	0.11	0.14
13.8	0	0	0	0.12	0	0	0
14.0	0	0	0	0	0	0	0

the seed in the cage was subjected to high pressure. As the choke was screwed out, therefore increasing the size of the opening, the pressure in the cage was reduced until a point was reached where not enough pressure could be generated to crush the seed. When the pressure was too high, the oil looked whitish as it oozed out which was thought to be due to the presence of minute particles of the kernel. These particles were being forced out instead of being crushed to recover the oil in them. As the size of the choke opening was increased, the quantity of oil recovered increased and the particles in the oil decreased until a peak was reached after which the quantity of oil recovered started to decrease. This later decrease was due to the reduced pressure in the cage. The two phenomena of low oil recovery at a small choke opening (higher pressure) and when processing oilseeds with low husk to kernel ratio are illustrated in **Fig. 1**. Sunflower and unshelled groundnut were processed at higher pressure resulting in higher EE although their oil contents were lower.

Oil was recovered down to the choke openings shown in **Table 2** for the different oilseeds. As the choke opening was increased, a point was reached at which the pressure in the cage fell abruptly to zero. This caused the jump in recovered oil from relatively large values to zero as shown in **Table 2** and illustrated in **Fig. 1**. The fall in the oil recovered from sesame was not as sudden as for the other seeds as some oil was recovered down to a choke opening of 13.8 mm. The possible explanation for this was that sesame cake was not free flowing, therefore, the residue pressure in the cage was high enough for some extraction to take place. Additionally, sesame seed is soft and therefore, easier to crush at relatively low pressure. On the other hand, sunflower cake is free flowing, therefore, the loss in pressure occurred much earlier at a choke opening of 13.1 mm.

Using the values in **Table 2** and oil content values in **Table 1**, the extraction efficiencies (EE) shown in **Table 3** were calculated for each oilseed and at the various choke openings. The maximum extraction efficiency achieved for hybrid sunflower, sesame, rapeseed, shelled groundnut and unshelled groundnut was 65.79 %, 48.36 %, 55.66 %, 50.92 % and 79.82 %, respectively. The highest extraction efficiencies were achieved with unshelled groundnut and hybrid sunflower, which had a high h/k ratio. Conversely, sesame, shelled groundnut and rapeseed whose h/k ratios were zero had relatively lower extraction efficiencies although their oil contents were high. However, the Kenya fedha and Kenya shaba varieties had high h/k ratios but their extraction efficiencies were very low. Although these varieties had relatively low oil contents, the difference in levels of oil content, h/k ratio and EE achieved was not proportional when compared with that for hybrid sunflower and unshelled groundnut. These observations pointed to the

Fig. 1 Variation of extraction efficiency with choke opening for different seeds

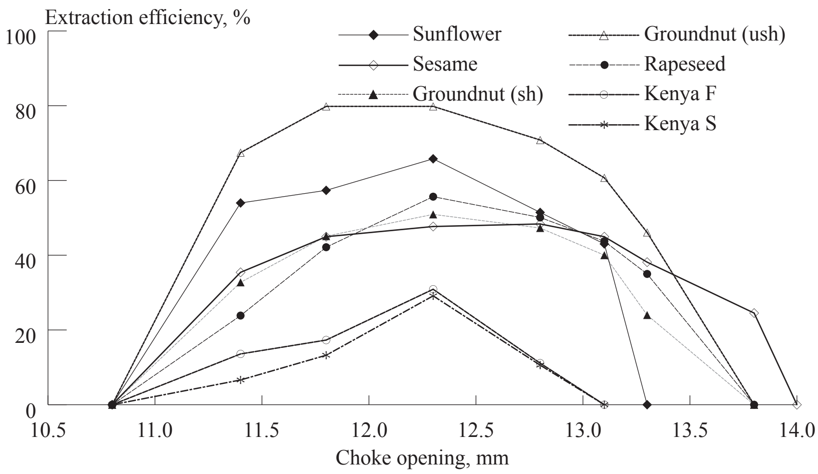

Table 3 Extraction efficiency achieved with different oilseeds

Choke opening, mm	Extraction efficiency for different oilseeds, %						
	Sunflower hybrid 98894	Sunflower Kenya *Shaba*	Sunflower Kenya *Fedha*	Sesame	Rapeseed	Groundnut (shelled)	Groundnut (unshelled)
10.8	0	0	0	0	0	0	0
11.4	12.83	6.58	53.98	36.78	24.99	37.79	70.59
11.8	16.04	13.05	57.35	44.95	44.98	49.60	80.67
12.3	25.69	22.84	65.79	47.00	57.47	54.32	80.67
12.8	12.83	9.79	51.45	49.04	54.97	51.96	73.95
13.1	6.42	0	43.02	47.00	47.48	44.87	60.50
13.3	0	0	0	38.82	37.48	25.98	47.06
13.8	0	0	0	26.56	0	0	0
14.0	0	0	0	0	0	0	0
lsd	3.02	3.5	4.51	2.2	2.51	1.99	3.0

need for the oilseed to have a balance between oil content and h/k ratio for the ram press to achieve high EE.

The difference in the maximum EE achieved with various oilseeds was significant at the 0.01 level. The EE achieved at various choke openings for each oilseed were also significantly different at the 0.05 level. As shown in **Table 3** and illustrated in **Fig. 1**, two or three values of EE around the maximum value were not significantly different for all oilseeds. This implied that the ram press could be operated at these openings without significantly affecting its performance.

Conclusion

This study showed that oil content and husk to kernel ratio of the oilseed influenced the extraction efficiency achieved by the ram press. For high extraction efficiency, there was need for the oilseed to have a balance between oil content and husk to kernel ratio. For high oil content and low fiber oilseeds; sesame, shelled groundnut and rapeseed, the extraction efficiencies achieved were relatively low. Conversely, the oil content and fiber content for sunflower hybrid 98894 and unshelled groundnut were balanced and their extraction efficiencies were relatively high. The Kenya fedha and Kenya shaba varieties had medium oil contents and high fiber contents that resulted in low extraction efficiencies. Soybean could not be processed with the ram press because of its hardness and very low oil content.

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Adaption of an Impeller Type Husker for Long Grain Rice

by

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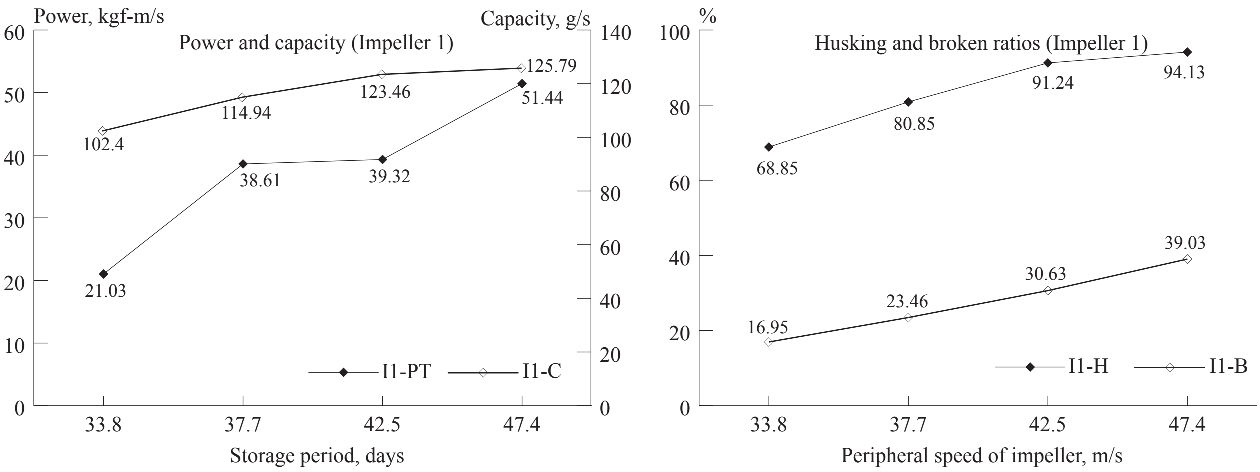
Abstract

Husking of short grain rice, Japonica, can be performed with the impeller-type rice husker at varying moisture content with less damage. The role played by friction and impact on the machine performance and quality of husking of long grain, Indica, was investigated on an impeller-type husker. In the first stage, analysis of variance showed that out of the four important parameters (speed, impeller-blade geometrical layouts, number of blades and the moisture content of the rice) the most significant parameter interaction was between speed and moisture (significant at both 95 % and 99 % level) and this interaction affected the power, husking-ratio, as well as the broken ratio. The moisture content affected the broken-ratio (significant at both 95 % and 99 %). In the second stage, it was found that higher impact increased the capacity and a peripheral velocity of 42.5 m/s at 27º to the tangent of the circumference of the impeller produced less broken-ratio.

Introduction

Husking is the removal of rice-husk from paddy rice. Ideally husking should not result in damage to the grain. However, this is practically impossible due to the complex nature of the factors involved. Forces of tension, compression and friction have been found to be involved in the husking process of the irregular structure of the paddy at varied moisture content (Arullo and De Padua, 1976). The performance of a husking machine is, therefore, not judged only on the basis of its husking efficiency and capacity, but also on the damage on the grain. Many machines have been designed worldwide to husk short grain paddy. However, there are three common types: under-runner disk huller, rubber-roll husker and impeller type husker. The impeller husker is designed based on centrifugal and coriolis forces, whereby the paddy is thrown against the liner part of the impeller housing. Husking depends primarily on

Fig. 1 Effect of peripheral speed of impeller 1



impact and friction. This husker produces high husking ratio for short grain rice even at high moisture content. However, little attention has been given to the testing of this type of husker on long grain rice.

In Japan, the rubber-roll and impeller type huskers are well-known. The rubber-roll husker is very popular from small-scale to large-scale, and from individual level to commercial level. The impeller type husker is, however, not yet used at the large-scale or commercial level yet.

A modified version of the impeller-type rice husker, manufactured by Otake Agricultural Machinery Company Limited, was used in this study for husking long grain paddy. Three types of new impeller-blades made of steel with various configurations were mounted on the husker. The husking process was evaluated on the basis of husking-ratio, broken-ratio, power and capacity. The moisture content, blade configuration, speed, and number of impeller-blades were the important parameters manipulated in this study. In order to reduce the number of runs, the experimental design of the study was based on the Orthogonal Array L16. The results of the study were then analyzed. The aim of this study was to adapt the impeller-type husker for long grain rice and to evaluate the machine performance.

Theoretical Considerations

The Impeller type husker was invented in the first half of the 1980s. It had higher husking efficiency even at higher moisture content. Higher efficiencies of over 97 % were obtained for short grain rice, (Omar et al., 1987; Nishiyama, 1992 and Wang et al., 1997). Husking ratios above 90 % could, however, be obtained at peripheral speeds higher than 43 m/s (Yamashita, 1993). Nishiyama (1991), derived a theoretical equation for the impeller type husker from the dynamics equation between a paddy grain and an impeller. This expression, to this day, forms the basis of designing of centrifugal huskers. The following laws of proportion were derived from the dynamics equations:

1. The law of proportion in terms of rotating angular velocity: If

Fig. 2 Effect of peripheral speed of impeller 2

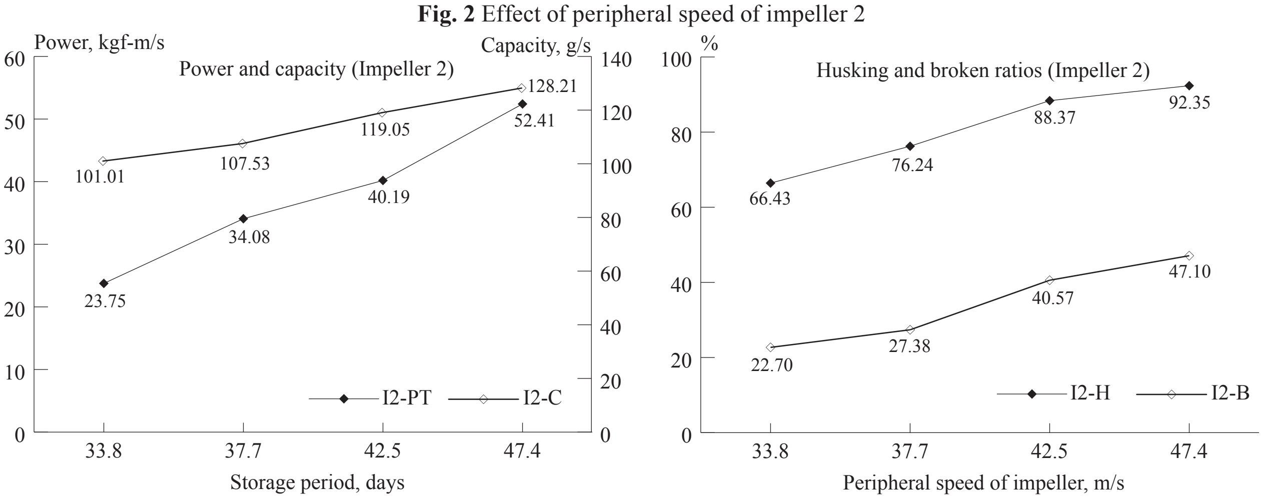
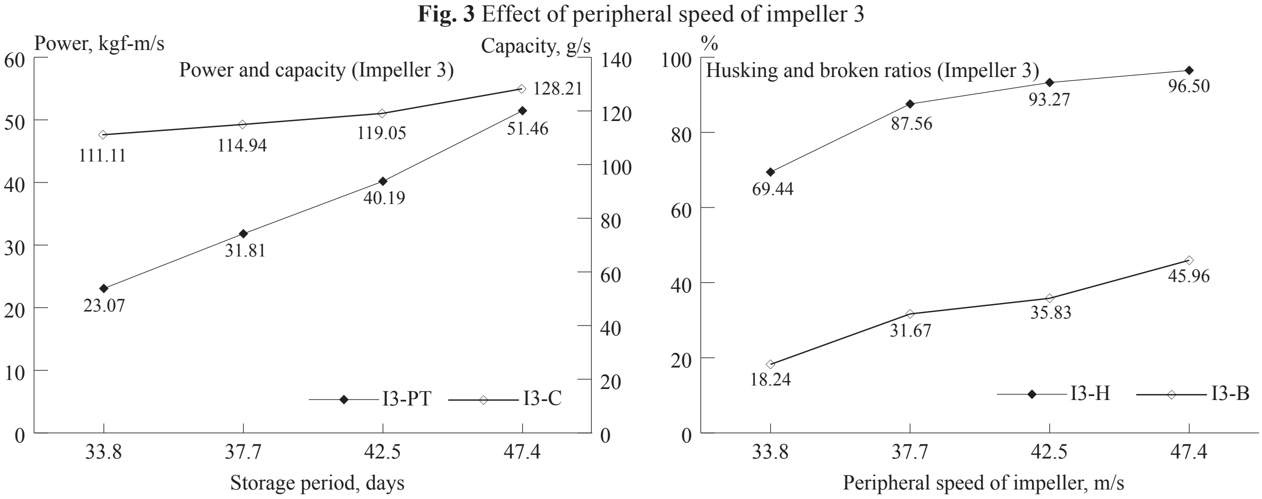


Fig. 3 Effect of peripheral speed of impeller 3



the initial grain velocity is proportional to ω or equal to 0, the grain velocity is proportional to ω; normal force, frictional force and energy are proportional to ω^2.

2. The law of proportion in terms of similarity ratio χ between similar blades with the rotating axis as the similarity center: If the initial grain velocity is proportional to χ or equal to 0, the grain velocity and force are proportional to χ, while the energy is proportional to χ^2.

In 1992, Nishiyama, showed that the energy required to husk rice increased with lower coefficient of friction between the paddy grain and the blade. Yamashita (1993) investigated the husking of paddy on both the impeller type husker and the rubber roll husker at various moisture contents. He concluded that the impeller husker could maintain a high husking ratio (over 90 %) even at moisture content above 20 %, in contrast the husking ratio of rubber roll husker sharply dropped when the moisture content was more than 16 %.

Wang et al. (1997) studied the relationship between frictional energy and husking quality. They concluded that the improved impeller, with an increased center angle of arc of the blade, gave lower broken ratio than the original impeller by about 8 % at the same husking ratio. Omar et al. (1987) examined an impeller husker with different rice varieties and found out that the long grain rice gave high broken ratio in comparison to the short grain rice. Shitanda et al. (1998) confirmed this result with a similar test on three varieties of rice (one short grain and two long grain varieties). The husking ratios of the three varieties were, however, over 97 % at about 2600 rpm.

Investigation into some important parameters of husking long grain rice with an impeller husker showed that the speed of the impeller was

Fig. 4 Comparison of the impellers

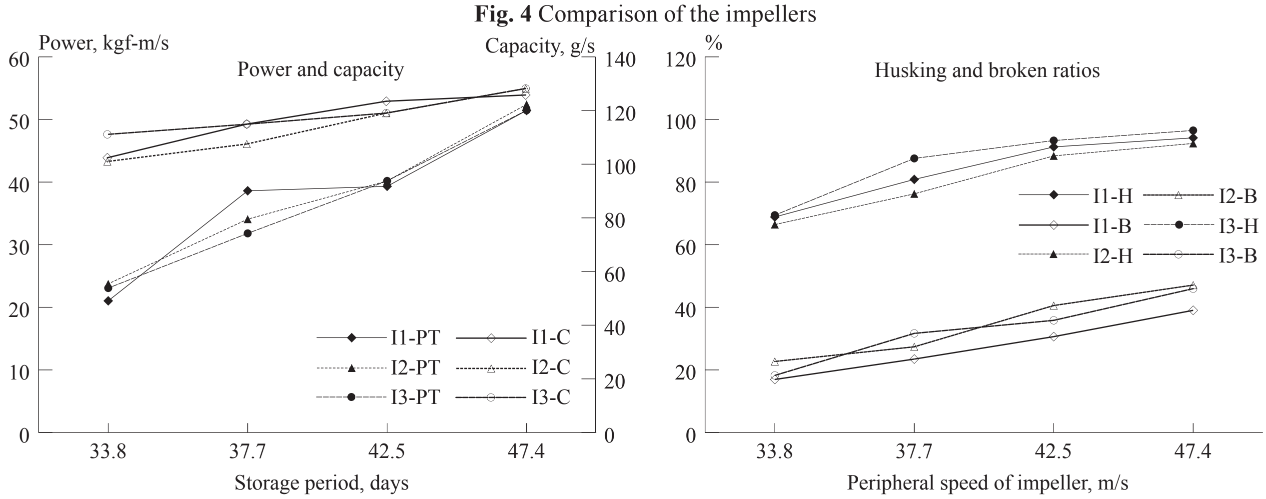


Table 1 Interaction between broken ratio, power, husk ratio and capacity

Power, kgf m/s; D_i = 412.7						**Broken ratio**, %; D_i = 255.6					
Analysis of variance	SS	D_f	Varience	F- Distribution	Efficiency, %	Analysis of variance	SS	D_f	Varience	F- Distribution	Efficiency, %
S	246.3	3.0	82.1	3.2		S	78.7	3.0	26.2	12.2	*,**
MxS	1,491.8	3.0	497.3	19.5	*,**	MxS	1,010.0	3.0	336.7	156.2	*,**
N	54.7	2.0	27.3	1.1		N	9.5	2.0	4.7	2.2	
M	0.1	1.0	0.1	0.0		M	250.5	1.0	250.5	116.2	*,**
E	152.8	6.0	25.5			E	12.9	6.0	2.2		
Total	1,945.7	15.0				Total	1,361.6	15.0			

Husk-ratio, %; D_i = 1,066.0						**Capacity**, g/s; D_i = 1,462.1					
Analysis of variance	SS	D_f	Varience	F- Distribution	Efficiency, %	Analysis of variance	SS	D_f	Varience	F- Distribution	Efficiency, %
S	1,609.4	3.0	536.5	17.7	*,**	S	72.1	3.0	24.0	0.2	
MxS	3,422.4	3.0	1,140.8	37.7	*,**	MxS	666.2	3.0	222.1	2.0	
N	198.5	2.0	99.2	3.3		N	297.2	2.0	148.6	1.3	
M	11.7	1.0	11.7	0.4		M	0.2	1.0	0.2	0.0	
E	181.8	6.0	30.3			E	682.8	6.0	113.8		
Total	5,423.8	15.0				Total	1,718.4	15.0			

*Significant at 95 % level, **Significant at 99 % level; SS: Sums of squares, D_f: Degrees of freedom the most effective parameter that affected both the husking ratio and the broken ratio. The liner and moisture content affected the broken ratio, whereas material of the impeller-blade showed little effect.

Materials and Methods

Materials

i. Sample Paddy- Two samples of long-grain paddy were used in this study (harvested in crop year 2000 and 2001). A sample size of 0.5 kg was used for each test run (**Appendix B**).
ii. A modified version of the Otake impeller type husker housing and liner.
iii. Three modified impellers made of mild steel.
iv. A one horse-power, three phase induction motor served as the driver (**Appendix A**).

Methods

1. Determination of Impeller Configuration

The predominant forces, centrifugal and coriolis, are responsible for the impact and friction phenomena that result in the husking of the paddy grain. The magnitude and direction of the impact is governed by the velocity and angle at the outlet of the impeller. The frictional force depends on the magnitude of the normal force and the coefficient of friction between the paddy and the contact surface. Based on these principles, three types of blades were manufactured, namely original impeller blade, inclined blade, and negative displacement blade (**Appendix B**).

2. Determination of Factors Affecting the Quality of Husked Long-Grain Rice.

With the important factors of speed, moisture content, impeller configuration and number of blades per impeller at levels of 4, 2, 3 and 3, respectively, the Orthogonal Array L16 was used to determine the test combinations to meet the 16 runs (**Appendix B**). In each test-run, a sample of 0.5 kg of the paddy was loaded into the hopper and with the husker in operation the feeding-gate was opened fully. A pen-recorder recorded the time and the torque. The throughput was collected from the outlet of the impeller-husker and by means of the sampler, a small sample-size of the output was obtained. This sample was analysed and the data fed into a spread-sheet program. Analysis of variance was used to establish the significances of the various factors.

3. Establishment of Optimal Parameters

Based on the results of step 3 above, a second test was carried out. The number of factors was reduced to two (speed, and blade configuration).

4. Determination of the Effect of Number of Blades on the Husking Process

The impeller with the best blade-

Fig. 5 Gross power and net-husking power

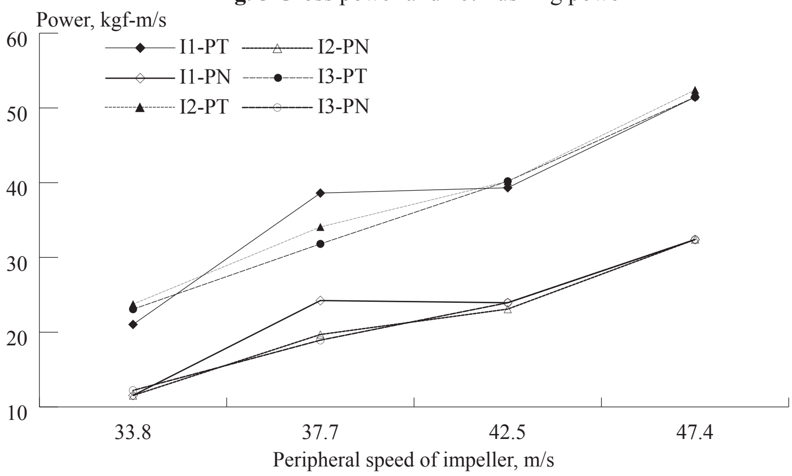
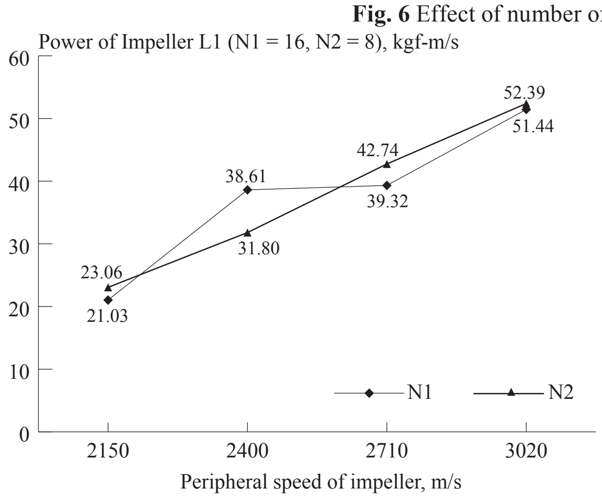
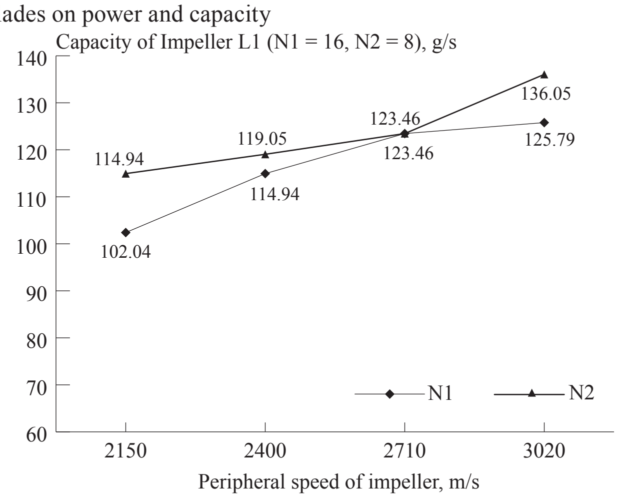


Fig. 6 Effect of number of blades on power and capacity





configuration was further tested to determine the effect of the number of blades on the husking process.

Results and Discussions

Analysis of Variance

Table 1 shows that the most effective parameter interaction was between moisture content (M) and speed (S) which showed a 99 % significance level on power, broken-ratio, and husking-ratio.

Rice-moisture content and speed were 99 % significant on the broken-ratio and husking-ratio respectively.

Optimal Parameters

1. Impeller 1 (Original Impeller-blade Version)

The results of husking long grain at different peripheral impeller speeds are shown in **Fig. 1**. The power increased appreciably at lower speeds as compared to higher speeds above 42.5 m/s. On the other hand, the capacity increased linearly with speeds. The husking-ratio curve depicted an initial high increase in husking with regards to increase in speed and a lower increase rate at speeds higher than 42.5 m/s. The reverse is the case with the broken ratio. The curves, therefore, indicated that an optimum speed in the neighbourhood of 42.5 m/s gave a husking-ratio of 91.24, broken-ratio of 30.63 %, and capacity of 39.3 g/s at the power requirement of 123.5 kgf-m/s.

2. Impeller 2 (Inclined Version)

The shapes of the curves (power, capacity, husking-ratio and broken-ratio) with respect to impeller speed were similar to those of impeller 1. However, the values of power, capacity, husking-ratio and broken-ratio at the optimum speed of 42.5 m/s were 119.1 kgf-m/s, 40.2 g/s, 88.4 % and 40.6 %, respectively, as indicated in **Fig. 2**.

3. Impeller 3 (Negative Displacement)

The curves of power and capacity against speed for this impeller showed almost a linear relationship without a peak (optimal) characteristic. The curves of husking-ratio and broken-ratio (**Fig. 3**) showed a lower increase of both husking and broken ratio from a speed of 37.7 m/s to 42.5 m/s. However, the broken-ratio increased sharply for speeds beyond 42.5 m/s.

4. Comparison between the Three Impellers

From **Fig. 4**, it can be deduced that impeller 2 had the poorest husking and broken ratios, and lower power requirement at appreciable capacity for respective peripheral impeller speeds.

On the other hand, impeller 3 gave the highest husking-ratio and an average broken-ratio of the three impellers. The power was, however, high but despite that it had the lowest capacity.

On the basis of the broken-ratio, impeller 1 could be said to have the best impeller-blade configuration, whereas, impeller 3 can also be said to have the best blade configuration on the basis of husking-ratio.

5. Power Required for Husking

Fig. 5 showed that the net-husking-power requirement increased correspondingly with increase in total power requirement. Net husking power forms more than 50 % of the gross power required.

Effects of Number of Impeller Blades

1. Power and Capacity

Fig. 6 indicates that the impeller with eight blades had both a slightly bigger gross power requirement and capacity as compared to the 16-blade impeller. This was due to the high volumetric flow rate.

Appendix A Experimental set up

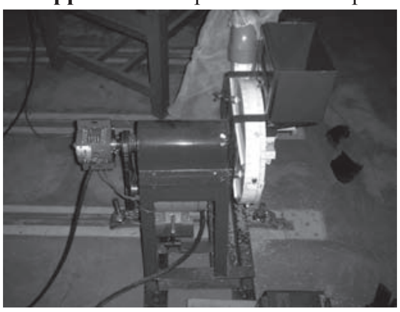
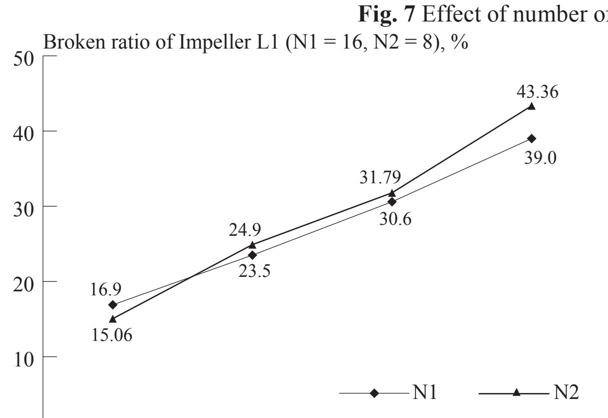
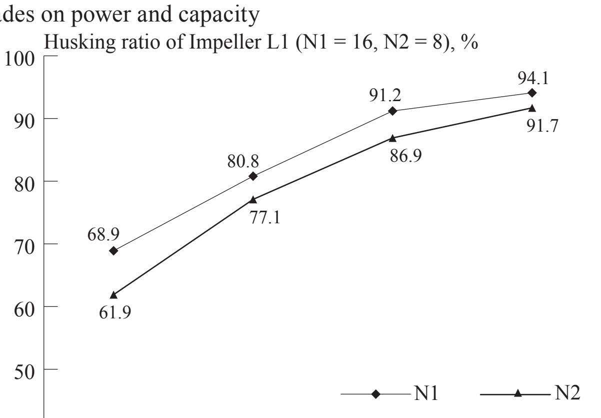


Fig. 7 Effect of number of blades on power and capacity





2. Broken-ratio and Husking-ratio

The broken-ratio was lower for a 16-blade impeller which also gave a higher husking ratio (**Fig. 7**).

Observation of both Husked and Partially-husked Paddy

A critical look at the output showed that most of the empty husk looked intact although the grain was out. The husks did not disintegrate with the removal of the rice kernels. It was also observed that the rice grain was discharged from the husk along the longitudinal axis of the paddy.

Conclusions

1. The increase in the number of blades slightly decreases the gross-power required as well as the capacity. Capacity reduction results in the decrease of the gross-power requirement.
2. An impeller made of a lighter material will result in a lower gross-power requirement considering the gross-power and the net-power.
3. An impeller with a higher number of blades will reduce the broken ratio. The capacity will decrease and the husking efficiency will increase.
4. The husking process of long grain paddy depends largely on the magnitude and angle of impact.
5. High friction resulted in high broken ratio.
6. The peripheral speed of the impeller of about 42.7 m/s is an optimal speed for an impeller-type rice husker for long grain.
7. An angle at outlet of about 27º was found to be optimal.

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Appendix B Data

Crop yr	Sample weight, g	Indica	Japonica	Immature	Others	Crack, %	M.C., %	Foreign M., %	Immature, %
2000	16.89	15.40	0.75	0.60	0.07	5.00	12.4	0.05	0.04
2001	22.04	19.64	0.32	2.05	0.03	13.00	12.8	0.02	0.09

Sample	Power, HP	Husk-ratio, %	Broken-ratio, %	Capacity, g/s
1	47.148	91.58	41.886	111.1
2	45.762	95.75	26.606	92.6
3	35.615	86.71	27.479	100.0
4	39.299	82.11	45.369	89.3
5	26.348	68.78	46.046	98.0
6	30.508	72.60	28.834	108.7
7	29.474	72.31	30.148	90.9
8	29.229	80.67	46.699	90.9
9	16.267	59.33	15.190	75.8
10	16.267	61.95	32.925	76.9
11	17.603	67.30	29.268	90.9
12	18.923	69.71	14.100	92.6
13	16.502	46.60	13.089	94.3
14	16.502	38.49	32.292	96.2
15	13.396	34.99	27.107	76.9
16	13.875	36.84	15.521	76.9
Di_{16} =	412.717	1,065.75	472.557	1,462.1

Impeller	Weight, g	Liner-impeller	Slope, º	Displace-ment	Radius	Arc-angle
I1	6.04	27	0	6	38	76.8
I2	5.98	27	11.6	-	38	65.3
I3	5.9	27	0	-6	38	63.9

Factors	Level	Description		
			rpm	m/s
Speed	4	S0	3,020	47.4
		S1	2,710	42.5
		S2	2,400	37.7
		S3	2,150	33.8
		S4	1,870	29.4
Impeller	3	I1		
		I2		
		I3		
Number	3	N1	16	
		N2	8	
		N3	4	
Rice	2	M1	Year 2001	
		M2	Year 2000	

Impact of Tractorization on Farming in India with Special Reference to the State of West Bengal

by

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Abstract

Mechanization of Agriculture has been treated as one of the instruments of agricultural development since mid sixties. Mechanical ploughing has been in great demand following gradual elimination of crop-livestock husbandry practices. Chronicle and seasonal shortage of human labour from place to place and from time to time necessitates the rise in demand for tractor ploughing and/or ploughing by power tiller. Also, there is a case for rising demand for tractor use in agriculture in order to bring back cost of economy in production which has been shattered by over exploitation of natural resources for agricultural purpose. Accordingly, a steady growth in sale and use of tractor and power tiller in farming has been observed over time and over the different states of India and significant impact of mechanized ploughing either by tractor or power tiller on productivity of selected crops, cropping intensity, labour absorption and cost reduction have been observed in West Bengal (India) agriculture.

Introduction

Traditional bullock ploughing has been replaced by mechanized ploughing with gradual inroads of tractors and power tillers in the agricultural sector since the sixties. Mechanization has been one of the instruments for modernization of agriculture and that is why the green revolution during mid-sixties was truly coined as "Bio- chemical and mechanical revolution". Demand for tractorization has, therefore, increased manifold but not to the extent as it happened incase of other inputs like high yielding varieties of seeds, chemical fertilizer and irrigation. Of course, there is an established premises for greater demand for tractor and power tiller for ploughing.

Causes of Rising Demand for Tractors/Power Tillers

Mechanization, in general, helps to dispense with animal and human labour. Drudgery of agricultural work, high cost of maintenance of draught animals, chronicle and seasonal shortage in human labour available for agricultural purpose, requirement of timely completion of certain agricultural operations in certain seasons and consideration to bring about scale economy in certain farm operations are all factors for farmers to adopt mechanization to varying extent depending upon physical and economic access to use of tractors/power tillers.

Again, use of tractors and power tillers can replace bullock power more than it can replace human labour. This is a fact no doubt, but it is also equally true that the gradual decline in bullock power from rural areas necessitates use of tractors and power tillers. Decline in bullock power is attributed to rising maintenance cost. Crop-livestock farming system is outmoded in a significant part of the country. Rather, raising cattle for milk production has shifted its base from rural to urban and semi-urban areas. Although labour engagement per unit of land area for individual crops diminish due to mechanization, total absorption of labour throughout the year increases via increase in cropping intensity resulting from timely completion of field work and growing more than one crop during a year. Moreover, tractorization induces farmers to invest more on irrigation, use of modern technology and thereby increases intensity of cultivation, which, in turn, necessitates use of more labour. Mechanization can be viewed from other angle also. Economic development requires that resources (including man power) be diverted gradually from agriculture to non-agriculture sector as the country progresses. Surplus labour force (existing and created through mechanization) can be fruitfully used for development of non- farm sector.

Further, there is also emerging a need for mechanization in Indian agriculture. Adoption of modern farm technology has brought about environmental hazards and imbalance in soil, water and climate through use of chemical fertilizer and toxic plant protection chemicals. Qualitative and quantitative deterioration in natural resources available for cultivation has been observed in many places. Over exploitation of ground water reserve and use of irrigation water have resulted in the development of salinity and alkalinity in some places and the emergence of arsenic problems in other places. Overall cumulative impact of all these has resulted partial or total factor productivity in agriculture to decline in some areas and/or to remain stagnant in other areas. Falling productivity raises cost per unit of production and with this has been added the problem of rising production cost and decline in real price of food grains. Here, mechanized ploughing and other farm operations, which are supposed to substitute labour use to a considerable extent, are a boon to the agricultural sector to keep the agriculture sustainable and vibrant. Mechanization of farming activities, be it for crops grown during monsoon season or crops grown during pre and post monsoon season, always bring about cost economy through the reduction in the use of human and bullock labour. So, farm mechanization can be viewed as a savior in the context of declining productivity arising from soil and water pollution/deterioration. It can be argued, therefore, that the rising cost per unit of production due to falling productivity trend and due to prevailing unfavorable input and output prices can be partially mitigated by resorting to farm mechanization.

Production and Sale of Tractor and Power Tiller Overtime in India

Demand for tractors and power tillers is reflected by sales performance for various tractor companies spread over the country. Purchase of tractors is sometimes spontaneous by the farmers with the help of their own funds; and sometimes farmers are provided assistance for owning tractors and power tillers and other services through subsidy scheme of financing initiated by Government of India.

Effective demand for tractors over time is presented in **Table 1** and the similar year-wise data for the power tiller are presented in **Table 2**. What is evident from these two tables is that the tractor sale reached its peak at 273,181 during 1999-2000. Thereafter, there was a sharp decline to 173,098 during 2002-03, but during the next years onward, the number again rose. Power tillers also registered a peak during 2000-2001 with 16,891 numbers. The sale also declined and, thereafter, again rose. Fluctuation in the number sold over the year is quite possible. Tractors and power tillers are durable resources that provide flow services in the farm sector. These are demanded by the farming community as a whole during a given year/period and as such are influenced, inter alia, by the inventory or stock of the tractors/power tillers as available in the farm sector.

State-wise tractor use is discernable from the **Table 3**. There appears wide variability in numbers from State to State. Tractor use has been expressed here by number of tractors per 100,000 hectare of gross cropped

Table 1 The trend in production and sale of tractors

Year	Tractors	
	Production	Sale
1985-1986	75,550	76,886
1990-1991	139,233	139,831
1995-1996	191,311	191,329
1996-1997	221,689	220,937
1997-1998	255,327	251,198
1998-1999	261,609	262,322
1999-2000	278,856	273,181
2000-2001	255,690	254,825
2001-2002	219,620	225,280
2002-2003	166,889	173,098
2003-2004	190,687	190,348
2004-2005	249,077	247,531
2005-2006	296,080	292,908

Table 2 Year wise production and sale of power tiller

Year	Power tiller	
	Production	Sale
1985-1986	3,706	3,754
1990-1991	6,228	6,316
1995-1996	10,500	10,045
1996-1997	11,210	11,000
1997-1998	12,750	12,200
1998-1999	14,480	14,488
1999-2000	16,891	16,891
2000-2001	17,315	16,018
2001-2002	14,837	13,563
2002-2003	14,438	14,613
2003-2004	15,849	15,665
2004-2005	17,750	17,500
2005-2006	18,100	18,000

Source: Govt. of India, economic survey, various issue, ministry of finance, New Delhi and information from website "agricultural implements and machinery"

Table 3 State-wise number of tractors per lakh hectare of gross cropped area overtime in India

States	1979-80	1984-85
Punjab	2,570	4,642
Haryana	448	1,897
Gujarat	322	624
U.P	457	878
Rajasthan	196	190
Assam	148	199
W.B	164	184
Karnataka	141	225
A.P	75	160
Orissa	27	32
M.P	36	152
Maharashtra	119	179
Bihar	82	165
T.N	132	180
Kerala	233	232
All India	230	426

Source: Centre for monitoring and Indian economy 1993 area (GCA). In terms of number, Punjab had the highest with 4642 followed by Haryana (1,897), U.P (878) and Gujarat (624) during 1984-85. Remaining other states lie below the all India average of 426 number per 100,000 hectare of GCA.

Regional Pattern of Acquisition of Tractors and Power Tillers Overtime in West Bengal and Their Density

West Bengal in India is a State dominated by marginal and small farmers as opposed to the States like Punjab, Haryana, U.P, and Maharashtra where there are comparatively larger concentration of medium and large farmers. The average size of land holdings in West Bengal is around one hectare, but this small size in no way an impediment to mechanization of the farming sector. There has been steady progress in acquisition of tractors and power tillers as per available data presented in **Table 4**. Leading districts in the acquisition of tractors are Burdwan (5,110), Hooghly (3,290), North 24 Pgs (1,305), Nadia (1,296) and Bankura (1,000) during 1997. During the same year, number of power tillers was the highest in Midnapore (3,847), followed by Hooghly (2,719), Howrah (1,542), Burdwan (1,253) and South 24 Pgs (984). It is also noted that while districts of Burdwan and Hooghly have high demand both for tractors and power tillers, Midnapore and Howrah districts, on the other hand, show their preference more for power tillers than for tractors. Soil type and economic condition of the farmers determines purchase of tractor/power tiller.

Distribution of districts according to tractor and power tiller density per unit area is another indication for physical accessibility of the farmers to use tractors/power tiller. This information is conveyed in **Tables 5** and **6**. There is substantial variation in number of tractors per thousand of net cropped hectare among the districts (**Table 5**). While there are 11 to 15 tractors per thousand of net cropped area in Howrah and Hooghly districts, only one and even less than one tractor covers thousands of net cropped hectare in 6 out of 17 districts in West Bengal. These districts are Jalpaiguri, Darjeeling, Coochbehar, Purulia and Dinajpur (U+D). Other districts are having tractors between 2 to 10 numbers per thousand net cropped hectare. When tractors and power tillers are both considered together per unit of land area, the situation improves a bit (**Table 6**).

Table 4 District wise distribution of tractors and power tillers in West Bengal overtime

State/district	Tractor			Power tiller		
	1989	1994	1997	1989	1994	1997
West Bengal	**5,542**	**11,125**	**16,900**	**7,115**	**10,756**	**13,783**
Burdwan	2,574	3,364	5,110	778	978	1,253
Birdhum	314	550	835	117	154	198
Bankura	253	658	1,000	47	623	798
Midnapore	362	627	952	1,777	3,002	3,847
Howrah	112	434	659	463	1,203	1,542
Hooghly	580	2,166	3,290	2,731	2,122	2,719
North 24Pgs	282	859	1,305	259	577	739
South 24Pgs	110	356	541	529	768	984
Nadia	408	853	1,296	151	588	754
Murshidabad	168	391	594	34	59	76
Dinajpur (U)	114	213	325	-	79	101
Dinajpur (D)	29	77	117	12	36	46
Malda	2	241	366	135	101	529
Jalpaiguri	127	117	178	50	120	154
Darjeeling	-	51	77	-	-	-
Coochbehar	53	112	170	32	345	442
Purulia	54	56	85	-	1	1

Source: Govt. of West Bengal, economic review, various issues, ministry of agriculture, New Delhi and information from website "agricultural implements and machinery"

Table 5 Distribution of districts according to tractor density

No.*	Districts
Up to 1 tractor	Jalpaiguri, Darjeeling, Purulia, Coochbehar, Dinajpur (U+D)
2 to 5 tractor	Nadia, Murshidabad, Midnapore, Malda, Birdhum, Bankura, 24Pgs(S)
6 to 10 tractor	Howrah, North24 Pgs
11 to 15 tractor	Burdwan, Hooghly

*No. of tractors per thousand net cropped ha
Source: Prepared using tractor numbers and net cropped area

Table 6 Distribution of districts according to the density of both tractors and power tiller combined

No.*	Districts
Up to 6	Jalpaiguri, Darjeeling, Coochbehar, Purulia, Dinajpur (U+D), Nadia, Malda, Murshidabad, 24Pgs(S), Midnapore, Birdhum, Bankura
7 to 12	24 Pgs(N), Nadia
13 to 18	Burdwan
19 to 24	-
25 to 30	Howrah, Hooghly

*No. of both tractors and power tiller combined per thousand net cropped ha
Source: Prepared using tractor numbers and net cropped area

Impact of Mechanization

Impact of mechanization in West Bengal agriculture has been treated with respect to its influence on productivity, labor use, cost reduction possibility and cropping intensity. The impact of mechanized ploughing in West Bengal agriculture is discussed taking tractor density and tractor plus power tiller density on the one hand and productivity of rice as a whole, winter rice, summer rice and potato respectively on the other. The tractor density, as already stated, refers here to number of tractors/power tillers or both per thousand net cropped hectare and the productivity means yields in kilograms/quintal per hectare, which relates to 2000-2001

Tractor density and rice productivity are presented in two way classified form to show their association in **Table 7a**. Rice productivity is seen to increase with the increase in tractor density. The rice bowel districts of West Bengal are observed to go for mechanization. The correspondence of these two variables has been estimated with the help of rank correlation co-efficient and these two variables are seen to be highly related with 'r' value 0.72, which is highly significant.

Tractor density and winter rice productivity has similarly been analyzed to show their association, but their 'r' value though positive, is not statistically significant indicating that the majority of the districts uses less tractors for ploughing in winter paddy cultivation (**Table 7b**). Of course, major winter rice producing districts, as usual, go for tractorization of the cultivation. The similar analysis has been attempted for summer rice, which exhibits positive significant association between tractor use and productivity (**Table 7c**). The analysis of the similar type for potato has also been attempted, which shows positive significant correlation between the two variables, and the so-called potato growing districts like Hooghly, Burdwan, and Midnapore are seen to use more and more of tractors hours in potato cultivation (**Table 7d**).

The distribution of the districts by productivity range and tractor density for the concerned crops discussed as above reveals that the districts with higher productivity are associated with higher number tractors per unit of area; and this is true for all crops and almost same districts reveals their same relative positions in all cases. This means that with the availability of tractor service farmers go for use of trac-

Table 7a Distribution of the districts of West Bengal by tractor density (no. of tractors per thousand net cropped ha) and productivity of rice (kg/ha)

Range*	Reporting districts under productivity range (NS, r = 0.72)				
	1400-1700	1701-2000	2001-2300	2301-2600	2601-2900
Up to 1	Jalpaiguri Darjeeling	Coochbehar Purulia	Dinajpur(U) Dinajpur(D)	-	-
1 to 5	-	-	24Pgs(S) Murshidabad Maldah	Birdhum Bankura Midnapore	Nadia
5 to 10	-	Howrah	-	24Pgs(N)	-
10 to 15	-	-	-	Hooghly	Burdwan

Table 7b Distribution of the districts of West Bengal by tractor density (no. of tractors per thousand net cropped ha) and productivity of winter rice (kg/ha)

Range*	Reporting districts under productivity range (NS, r = 0.25)				
	1400-1650	1651-1900	1901-2150	2151-2400	2401-2650
Up to 1	Jalpaiguri Darjeeling	Dinajpur(U) Coochbehar Purulia	Dinajpur(D)	-	-
1 to 5	Nadia Murshidabad	24Pgs(S)	Midnapore Maldah	Birdhum	Bankura
5 to 10	Howrah	24Pgs(N)	-	-	-
10 to 15	-	-	Burdwan	Hooghly	-

Table 7c Distribution of the districts of West Bengal by tractor density (no. of tractors per thousand net cropped ha) and productivity of summer rice (kg/ha)

Range*	Reporting districts under productivity range (NS, r = 0.546)				
	2000-2400	2401-2800	2801-3200	3201-3600	3601-4000
Up to 1	Jalpaiguri Coochbehar	Darjeeling Purulia	Dinajpur(U) Dinajpur(D)	-	-
1 to 5	-	24Pgs(S)	Midnapore	Birdhum Bankura Nadia Murshidabad Maldah	-
5 to 10	-	Howrah	24Pgs(N)	-	-
10 to 15	-	-	Hooghly	-	-

Table 7d Distribution of the districts of West Bengal by tractor density (no. of tractors per thousand net cropped ha) and productivity of potato (kg/ha)

Range*	Reporting districts under productivity range				
	135-170	171-205	206-240	241-275	276-310
Up to 1	Darjeeling Purulia	Dinajpur(U) Dinajpur(D)	Jalpaiguri Coochbehar	-	-
1 to 5	-	Maldah	Birdhum 24Pgs(S)	Bankura Midnapore Nadia Murshidabad	-
5 to 10	-	-	24Pgs(N)	Howrah	-
10 to 15	-	-	-	Burdwan	Hooghly

*Range of tractor density
Source: Prepared from the data available from statistical abstract, 2000-2001, Bureau of applied economic research, govt. of West Bengal

tors in all crop production.

Tractor and Power Tiller Combined Density vs. Productivity

Mechanical ploughing by tractor is not the total picture of West Bengal. Power tiller use in cultivation is very much significant in West Bengal as sale and use of power tiller is maximum here compared to any other States. So, ploughing by tractor and power tiller is expected to give better association with crop productivity. Accordingly, analyses similar to that of tractor use have been attempted for tractor and power tiller combined uses and its density. These tabular analyses are contained in **Tables 8a** to **8d**. However, the distribution of districts on the basis of tractor and power tiller density and productivity did not highlight better association between them for crops considered except for potato where association is much higher positive order (r = 0.83). In fact, power tiller numbers and uses are more observed in the potato growing districts of West Bengal,such as Hooghly, Burdwan, Midnapore, and Howrah. Power tillers are used in other districts for potato and other crops also.

Table 8a Distribution of the districts of West Bengal by tractor and power tiller combined (no. of per thousand net cropped ha) and productivity of rice (kg/ha)

Range*	Reporting districts under productivity range (NS, r = 0.54)				
	1400-1700	1701-2000	2001-2300	2301-2600	2601-2900
Up to 6	Jalpaiguri Darjeeling	Coochbehar Purulia	24Pgs(S) Dinajpur(U) Dinajpur(D)	Birdhum Bankura Midnapore Murshidabad Maldah	-
6 to 12	-	-	24Pgs(N)	-	Nadia
12 to 18	-	-	-	-	Burdwan
18 to 24	-	-	-	-	-
24 to 30	-	Howrah	-	Hooghly	-

Table 8b Distribution of the districts of West Bengal by density of tractor and power tiller combined (no. per thousand net cropped ha) and productivity of winter rice (kg/ha)

Range*	Reporting districts under productivity range (NS, r = 0.208)				
	1400-1650	1651-1900	1901-2150	2151-2400	2401-2650
Up to 6	Murshidabad Jalpaiguri Darjeeling	24Pgs(S) Dinajpur(U) Purulia Coochbehar	Midnapore Dinajpur(D) Maldah	Birdhum	Bankura
6 to 12	-	Nadia	24Pgs(N)	-	-
12 to 18	-	-	-	-	Burdwan
18 to 24	-	-	-	-	-
24 to 30	-	Howrah	Hooghly	-	-

Table 8c Distribution of the districts of West Bengal by density of tractor and power tiller combined (no. per thousand net cropped ha) and productivity of summer rice (kg/ha)

Range*	Reporting districts under productivity range (NS, r = 0.313)				
	2000-2400	2401-2800	2801-3200	3201-3600	3601-4000
Up to 6	Jalpaiguri Purulia	24Pgs(S) Darjeeling Coochbehar	Midnapore Dinajpur(U) Dinajpur(D)	Birdhum Bankura Murshidabad Maldah	-
6 to 12	-	Nadia	24Pgs(N)	-	-
12 to 18	-	-	-	-	Burdwan
18 to 24	-	-	-	-	-
24 to 30	-	Howrah	Hooghly	-	-

Table 8d Distribution of the districts of West Bengal by density of tractor and power tiller combined (no. per thousand net cropped ha) and productivity of potato (qtl/ha)

Range*	Reporting districts under productivity range (NS, r = 0.83)				
	135-170	171-205	206-240	241-275	276-310
Up to 6	Darjeeling Purulia	Murshidabad Dinajpur(U) Dinajpur(D) Maldah	Birdhum 24Pgs(S) Jalpaiguri Coochbehar	Bankura Midnapore	-
6 to 12	-	-	24Pgs(N)	Nadia	-
12 to 18	-	-	-	Burdwan	-
18 to 24	-	-	-	-	-
24 to 30	-	-	-	Howrah	Hooghly

*Range of tractor and power tiller density
Source: Prepared from the data available from statistical abstract, 2000-2001, Bureau of applied economic research, govt. of West Bengal

Tractor Intensity vs. Cropping Intensity

Again, it is to be kept in mind that the association between tractor use and productivity is abstract in the sense that tractor use, as such, has less direct influence to enhance productivity, but in a passive away it affects productivity through timely completion of some operation and through the impetus given to the tractor users to invest more of other coordinating inputs, which help in rising productivity.

If the aggregate productivity considering all concerned crops could have been taken, then more meaningful association between productivity and density would have been visible. In absence of aggregate production and productivity data, relation could be established between cropping intensity (proxy for aggregate output) and tractor density. Distribution of the districts on the basis of density of tractor plus power tillers and cropping intensity (**Table 9**) shows a positive association between them signifying that mechanization enhances cropping intensity.

Labour Use vs. Mechanization

Mechanization normally is known to be labor substituting, which is thought to be anti- establishment, but the field level primary survey data on Farm Management and cost of production of crops conducted by the Directorate of Agriculture, Government of West Bengal reveals a contrary situation with respect to labour use and mechanization. Labour use (hrs/ha) in mechanized farm is no less rather sometimes more than those of non-mechanized one in all but potato (**Table 10**). In case of potato, mechanized farms enjoy, to some extent, labor use economy. Of course, mechanization in aggregate feature is labour additive, i.e. labour use per farm throughout the year is expected to be higher in mechanized farms than in non-mechanized through the rise in cropping intensity, which, in turn, engages more labour per farm within an agricultural year.

Mechanization vs. Cost Reduction

Mechanization is beneficial in so far as cost reduction possibility is concerned. To substantiate this aspect, average cost of production per quintal between mechanized and non-mechanized farms for concerned districts relating to four crops are analyzed and also presented in **Table 10**. It is evident that the mechanized farms undoubtedly were cost reducing for jute, summer rice and potato. In case of winter rice cost reduction was not visible probably because of uncertainty in yield and the cultivation being dependent on monsoon, and because of other natural hazards developing during monsoon months.

Concluding Remarks

It is, thus, observed from the above discussion that farm mechanization can increase productivity, can enhance labor use and can help reducing production cost. These advantages of farm mechanization can be used to compensate losses incurred in production due to deteriorating health of water, soil and environment developed from uncontrolled chemical and water use in agriculture for production. The physical and economic access to use tractors and power tillers needs to be strengthened even more by proactive implementation of subsidy schemes of financing, and by establishment of custom hiring service units.

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Table 9 Distribution of by density of tractor and power tiller combined (no. per thousand net cropped ha) and cropping intensity in percentage in West Bengal

Range*	Reporting districts under cropping intensity range (NS, r = 0.72)				
	100-130	131-160	161-190	191-220	221-260
0 to 6	Darjeeling Purulia	Bankura 24Pgs(S)	Midnapore Birdhum Dinajpur(D) Dinajpur(U) Jalpaiguri	Maldah Coochbehar	Murshidabad
7 to 12	-	-	24Pgs(N)	-	Nadia
13 to 18	-	-	Burdwan	-	-
19 to 24	-	-	-	-	-
25 to 30	-	-	-	Howrah	Hooghly

*Range of tractor and power tiller density
Source: Prepared from the data available from statistical abstract, 2000-2001, Bureau of applied economic research, govt. of West Bengal

Table 10 Labour use and cost per ha between mechanised farm (MF) and non-mechanised farm (NMF)

	Jute		Winter rice		Summer rice		Potato	
	MF	NMF	MF	NMF	MF	NMF	MF	NMF
Av. labour hr/ha of reporting districts	216	213	149	152	206	179	243	265
Av. cost per quintal of reporting districts	678	749	425	379	444	485	202	294

Source: Prepared from the field survey data contained in "Study on farm management and cost of production of crops in W.B.", 1998-99, directorate of agriculture, government of West Bengal

The Present State of Farm Machinery Industry

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Outlook of Agriculture

Trend of Agriculture

In 2003 agricultural total products was ¥3,930 billion, accounting for 1.1 % of GNP. The agricultural products imports was ¥4,301 billion in 2002, ¥4,368 billion in 2003, ¥4,575 billion in 2004. The agricultural products exports was ¥206 billion in 2002, ¥196 billion in 2003, 204 billion in 2004.

Japan depends on imports for large part of domestic consumption of feed cereals, soybean, wheat. Food self-sufficiency rate was 40 % by calorie base in 2004, 28 % for cereals, almost the same as preceding year.

Population mainly engaged in farming has been decreasing yet, 2.57 million in 2004, 4.1 % of total working population. The number of Farm houses decreased to 2.93 million in 2004. 74 % of them are commercial farms selling their products in market. Total arable land in Japan was 4.71 million ha in 2004.

Japanese have been getting to enjoy more a variety of food since 1970's. The production of rice, oranges, milk, eggs has exceeded domestic consumption. Under such circumstances, GATT New Round Agreement gave great impact to Japanese agriculture. In order to get world competitive power, saving of production cost became the urgent issue. Other big issues in Japanese agriculture are, to have enough people engaged in farm work to maintain stable agriculture, production of high quality and safe products to meet the needs of consumers, and preservation of natural environment in rural areas.

In July 1999, Japanese government enacted the New Agricultural Stable Law, which aims to assure constant food supply by raising domestic production, to encourage multi-functions of agriculture, to have sustainable development of agriculture and to promote the development of rural areas. In the "Basic Plan for Food, Agriculture and rural Areas" established in 2005, the government set the target for food self-sufficiency ratio to 45 % on calorie basis, 76 % on productive value basis by 2015. "Rice and Vegetable Farming Management Stabilization Program" started in 2007 to strengthen domestic agriculture and improve self-sufficiency ratio. In this program conventional measures to encourage production individual commodities such as wheat, barley, and soybean are replaced by new farm management stabilization programs targeted at principal farmers.

Trend of Farm Mechanization

Agricultural mechanization in Japan has remarkably progressed in the field of low land rice, chief crop, in a short period since 1955. Now rice production is almost mechanized from planting to harvesting. In 2005, average working hours on 10a paddy field reduced to 30.0 hours from 117.8 hours in 1970.

In recent years farm machinery for rice crop is developed to be larger-sized, higher-efficiency and more commonly used. In addition, farm machinery for field crops and live stock farming is being developed and improved, which had been lagged behind so far.

From 1993 to 1997, government carried out Urgent Development Project to intensify the development of high performance farm machines to raise farm productivity and reduce farm work burden. From 1998 to 2002, government carried out 2nd Urgent Development Project to develop new machines for 21st century which are useful in environmentally kind agriculture and useful for labor saving in mountains area. The government has carried out "Next Generation Agricultural Machinery Urgent Development Project" since 2003. Under these projects, 46 types of high performance machines were developed. They are, a large all-purpose combine, a full automatic vegetable transplanters, riding-type vegetable cultivator, Japanese leek harvesting machine, infrared grain dryer, roll baler for chopped material, and a pesticide application nozzle with less chemical drift.

In 1995 Ministry of Agriculture, Forestry and Fisheries made a committee which studied method to reduce cost of farm product materials like farm machines. Those farm product materials are major parts of farming cost. In 1996 concrete movement started in the field of production and distribution. Low cost machinery with limited functions has been increasing.

Following are the numbers of farm machines in farm household of Feb. 1, 2005: riding tractor reached 1,942,000 units; rice transplanter 1,244,000; head feed combine 991,000.

Shipments of major farm machinery in the domestic market in 2006 are as follows: riding tractor 56,095 units (under 20 PS were 12,617; 20-30 PS 24,569; 30-50 PS 11,702; over 50 PS 7,207); walking tractor 158,858; rice transplanter 42,161; combine head feed types 29,367; standard types were 679; grain dryer 24,436; huller 19,818. The shipment of safety cabins and safety frames attached to tractors rose sharply to 55,910 units.

Plans for Farm Mechanization

2006 government budget for farm mechanization was used for;

- Development of high-performance machine and technology; "Next Generation Agricultural Machinery Urgent Development Project" in collaboration with manufacturers, universities and institutions promoted the development and popularization of the machines needed in local agriculture and sustainable agriculture.
- Saving of agricultural machinery cost: education for cost saving, raising farm work contractors.
- Prevention of farm accident.

Table 1 Major farm machinery on farm (Unit: thousand)

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Binder	Combine	Rice dryer
1970	3,269	183	32	2,178	261	45	1,227
1975	3,426	501	740	2,607	1,327	344	1,497
1980	2,752	1,471	1,746	2,139	1,619	884	1,524
1985	2,579	1,854	1,993	2,151	1,518	1,109	1,473
1990	2,185	2,142	1,983	1,871	1,298	1,215	1,282
1995	1,344	2,123	1,650	1,714	836	1,120	1,052
2000	1,048	2,028	1,433	1,269	583	1,042	861
2005	-	1,943	1,244	1,206	-	991	-

Source: "Statistical Yearbook of Ministry of Agriculture, Forestry and Fisheris" by the Ministry of Agriculture, Forestry and Fisheries.

Table 2 Shipment of major farm machinery (Unit: number)

Year	Walking type tractor	Riding type tractor	Rice trans-planter	Power sprayer	Binder	Combine	Rice dryer
1999	180,511	72,533	59,529	164,656	12,010	40,822	38,720
2000	166,996	72,554	55,386	162,030	10,648	40,888	33,159
2001	145,557	65,933	47,285	154,516	8,019	35,685	29,585
2002	142,774	64,781	48,054	150,035	6,991	34,397	28,893
2003	157,470	66,287	47,303	149,949	5,680	34,137	27,609
2004	142,316	60,964	45,065	154,049	5,421	31,136	30,435
2005	149,112	62,227	43,916	150,470	5,620	33,527	27,285
2006	158,858	56,095	42,161	127,219	4,765	30,046	24,436

Source: "Survey of Shipment of Agricultural Machinery" by the Ministry of Agriculture, Forestry and Fisheries.

Government Budget for Agriculture, Forestry and Fisheries

2006 government budget for agriculture, forestry and fisheries was 2,967.2 billion yen in total. Major subject items are;

- Securing and fostering principal farmers
- Development of innovative farming technology
- Supply of safe food and reinforcement of risk management
- Promotion of farm products export
- Activation of rural areas
- Use of biomass
- Maintenance of diversified and healthy forest

Movement of Farm Machinery Industry

The annual output of Japanese farm machines continues to decrease after the peak output of 650 billion yen (statistics by Japanese government) recorded in 1995. The annual output in 2006 was 495 billion yen (statistics by Japanese Farm Machinery Manufacturers' Association). The decline is affected by ongoing structural change in Japanese agriculture. Those are, considerable decline in the number of farm households and farmers exceeding the farm land decreasing, aging of farmers, decline in the demand for rice and production adjustment by the government. Aging farmers with no successors and small scale farmers have more tendencies to leave their farm works to contractors. The demand for agricultural machines is shifting to larger size, though total demand is going down. The government introduced "Rice and Vegetable Farming Management Stabilization Program" in 2007. This new program, however, requires that the

Table 4 Farm equipment distributor and sales value (Unit: million yen)

Year	No. of retailers (1)	Employes	Annual sales value (2)	Inventory	Square meters of shop m^2	Annual sales value (2)/(1)
1985.6	9,142	43,921	946,507	144,837	985,453	103.5
1988.6	9,444	45,952	1,015,304	159,798	923,726	107.5
1991.6	9,480	45,705	1,158,924	170,104	984,700	122.2
1994.6	8,838	43,112	1,128,087	166,298	978,788	127.6
1997.6	8,820	45,090	1,265,902	170,350	901,851	143.5
2002.6	8,123	40,441	979,066	145,725	982,529	120.5

Source: Ministry of Economy, Trade and Industry.

farmers eligible for support satisfy production adjustment condition, reduce production cost and improve farm management on their own program. For the present, while effective utilization of farm machines is key issue in Japanese agriculture, as the way of possession and utilization of farm machines are not established yet, farmers put off investing to farm machines. With declining demand for farm machines, absorption and consolidation in a part of farm machinery industries, job changing or closing of farm machinery dealers increased in 2007. Both farm machinery manufacturers and dealers are faced with severe management.

Trend of Farm Machinery Production

Farm machinery production in 2007 amounted to ¥459.2 billion (7.2 % decrease over the preceding year) by JFMMA (Japan Farm Machinery Manufacture's Association) statistics. The production for domestic market was 275.1 billion yen, 88.2 % of the preceding year. The production for export was 184.1 billion yen, 100.7 % of the preceding year.

Production of the major farm machinery is as follows: Riding type tractor 192,311 units decreased by 5.8 % over the preceding year. By horse power (wheel type), those under 20 PS amounted to 17,555 units, 20-30 PS 68,178 units, 30-50 PS 67,745 units, over 50 PS 37,430 units. About 70 % of the total production is for export.

The production of walking tractor amounted to 196,000 units, which showed an increase of 17.5 % over the preceding year.

The production of combine, which is next to the riding tractor in production amount, is 25,969 units (a decrease of 21.4 % than the preceding year). The most popular type is with harvesting width of one meter head feed.

Following are the production of

Table 3 Yearly production of farm machinery (Unit: number, million yen)

Year	Total		Walking type tractor		Riding type tractor		Rice transplanter		Power sprayer		Running type sprayer	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1998	-	491,973	212,551	29,669	144,774	194,954	53,122	46,218	156,890	7,256	7,973	9,204
1999	-	539,960	253,817	36,365	156,452	220,047	58,137	43,146	153,118	7,416	7,194	9,282
2000	-	520,956	243,995	31,647	163,536	204,339	56,784	44,887	162,527	7,763	6,000	9,896
2001	-	453,946	191,941	25,372	135,353	170,063	50,918	41,887	139,360	6,036	6,465	9,854
2002	-	456,024	174,683	22,172	149,202	184,843	47,911	40,696	191,940	7,953	4,907	7,691
2003	-	450,156	164,536	21,431	174,514	202,519	51,457	44,643	173,047	12,774	4,716	6,715
2004	-	478,039	194,018	24,444	190,116	234,100	47,522	42,606	184,221	14,881	3,984	6,421
2005	-	504,336	199,864	25,810	199,581	248,287	49,631	45,121	162,511	11,715	3,611	6,145
2006	-	494,990	166,856	21,418	204,064	259,760	50,562	46,881	164,722	9,083	3,247	5,456
2007	-	459,223	196,000	24,208	192,311	241,599	43,050	43,188	161,513	9,172	2,803	5,053

Year	Grain reaper		Brush cutter		Grain combine		Rice husker		Dryer		Grain polisher	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
1998	8,631	2,336	1,012,372	22,236	40,196	103,435	28,113	10,705	32,968	26,543	39,729	3,588
1999	11,816	3,436	1,084,889	24,172	42,173	112,145	37,579	14,491	36,920	29,976	36,342	2,464
2000	11,291	3,104	1,011,889	23,132	41,137	100,671	26,089	9,784	35,780	29,227	39,235	7,667
2001	8,172	2,274	963,965	20,200	36,158	91,210	23,973	9,209	31,567	26,007	36,427	6,972
2002	6,779	1,853	952,898	19,715	35,658	94,608	21,630	8,347	32,160	25,697	25,006	3,842
2003	5,664	1,521	836,409	19,333	36,899	90,811	26,174	9,827	27,419	21,730	27,975	1,825
2004	5,116	1,451	901,688	20,195	31,251	85,375	23,305	8,288	28,761	22,229	29,106	1,857
2005	5,940	1,686	890,978	20,391	37,340	99,996	22,373	8,304	27,111	22,143	25,846	1,518
2006	5,097	1,392	973,807	19,153	33,049	89,779	21,372	7,561	25,282	20,990	25,188	1,394
2007	3,217	910	1,233,084	25,060	25,969	74,049	17,585	6,660	21,205	17,341	23,475	1,389

Source: 1996-2002; "Survey of Status of Machinery, Production" by the Ministry of Economy, Trade and Industry,
2003-2007; JFMMA (Japan Farm Manufacture's Association statistics.

other types of farm machinery; rice transplanter amounted to 43,050 units a decrease of 14.9 % than the preceding year), grain dryer 21,205 units (a decrease of 16.1 %), huller 17,585 units (a decrease of 17.7 %), bush clutter 1,233,084 units (an increase of 26.6 %), power pest-controller 221,190 units (a decrease of 2.4 %), binder (walking type cutter for rice and wheat) 3,217 units (a decrease of 36.9 %), thresher 1,624 units (a decrease of 28.2 %), fodder cutter 23,925 units (a decrease of 26.2 %), rice pearling machine 23,475 units (a decrease of 6.9 %), rice sorter 14,620 units (a decrease of 20.0 %), farm carrier 14,157 units (a decrease of 10.6 %).

Trend of Farm Machinery Market

In Japan distribution systems for farm machinery is roughly divided into two major channels; the farm machinery dealers and Agricultural Cooperatives Association. As of June 2002, there were about 8,100 retail shops and about 40,000 employees, and the annual sales amounted to ¥979 billion.

According to the governmental survey by Ministry of Agriculture, Forestry and Fisheries, the total sales of farm machinery by Agricultural Cooperative Association was ¥271.7 billion in 2004 (¥272.4 billion in 2003). The number of Agricultural Cooperative was 913 in 2004. Average sales amount per co-operative decreased to ¥300 million.

About half of private dealers are small firms which less than 5 employees. In a long time view, with less demand for agricultural machines expected in future, improvement of management structure will be needed.

Export and Import of Farm Machinery

Export

In 2007 the export of farm machinery amounted to ¥268.7 billion, which showed an increase of 3.8 % over the preceding year.

By the export destination, ¥126.2 billion for North America (a decrease of 13.7 %), ¥54.0 billion for Europe (an increase of 22.6 %), ¥70.6 billion for Asia (an increase of 30.2 %). For North America, ¥116.8 billion was for U.S.A., tractor 93,449 units, ¥101.4 billion, which was a major part. Tractors for Asia is about 57,928 units, but maker's shipment is about 10,000 units, others are considered to be secondhand machines.

By the types of machines, tractor (consists main part of export); 204,636 units were exported in 2007, it amounted to ¥179.5 billion. Seeing by horse power, those under 30 PS amounted to 104,038 units, those from 30 to 50 PS 67,194 units, those over 50 PS 33,404 units.

Major farm machinery, next to tractor, is bush cutter. The total exports were 1,462,830 units, ¥29.5 billion. The exports of other farm machinery are as follows; walking tractor 51,128 units; power sprayer 52,480 units; lawn mower 93,945, units; grass mower 39,108 units; chain saw 421,110 unit, etc.

Import

In 2007 the imports of farm machinery amounted to ¥42.6 billion, which means a decrease of 9.7 %

(continued on page56)

Table 5 Export of farm equipment 2007 (Unit: FOB million yen)

Year	Unit	Value	Ratio	Major destinations
2000		139,049		
2001		126,173		
2002		148,581		
2003		160,734		
2004		200,533		
2005		225,131		
2006		258,772		
2007		268,694	100.0	USA, Korea, France
Seeder, planter	10,912	9,019	3.4	Korea, China
Power tiller	51,128	3,507	1.3	Vetnum, Belgium
Wheel tractor	204,636	179,463	66.8	USA
Power sprayer	52,480	1,761	0.7	Korea, Mexico, USA
Lawn mower	93,945	8,124	3.0	France, Brazil, UK
Brush cutter	1,462,830	29,509	11.0	USA, Italy, France
Mower	39,108	1,957	0.7	France, USA, Thai
Combine	2,754	7,682	2.9	Korea, China, Taiwan
Grain separator	651	3,408	1.3	India, Korea, Thai
Chain sow	421,110	9,225	3.4	USA, Italy, France
Others	-	15,039	5.6	

Table 6 Import of farm equipment 2007 (Unit: CIF million yen)

Year	Unit	Value	Ratio	Major destinations
2000		25,825		
2001		32,603		
2002		33,988		
2003		36,828		
2004		40,719		
2005		44,742		
2006		47,216		
2007		42,617	100.0	China, France
Wheel tractor	1,541	8,626	20.2	France, UK, Italy
Pest control machine	-	2,403	5.6	China, Taiwan
Lawn mower	332,619	4,475	10.5	China, USA, France
Mower	7,944	2,071	4.9	China, Italy
Hay making machine	631	517	1.2	France, Germany, NL
Bayler	363	1,054	2.5	France, Germany
Combine	92	1,262	3.0	Germany, China
Chain sow	61,094	959	2.3	China, Taiwan
Others	-	21,250	49.9	

Source: Ministry of Finance. Totaled by Japan Farm Machinery Manufactures' Assn.

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.

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Minimizing Fluctuations of Draught Forces During Tillage Operation Using Animal Drawn Ard Plough (Maresha): Zewdu Abdi, Academic and Research V/President Adama University, P. O. Box 3151, Adama, Ethiopia; **H. C. P. de Vries**, Docent Wageningen Agricultural University, Dept of Agricultural Engineering and Physics, Bomenweg 4, 6703 HD, Wageningen, The Netherlands.

The draught force with draught animals varies due to the breaking of clods, displacing of soils and when the share of the plough is confronted with harder materials. This effect results in the vibration of the wooden yoke that causes sore neck and fatigue to the oxen. It also impairs their capacity to produce sustained tractive effort over a long time and gradually reduces tractive effort produced by the draught animals. The vibration of the implements, additionally, results in an uneven furrow.

Measurements of draught force were taken with a shear type strain gage. The measured forces were plotted against time. For each test, the mean draught force along with the variation from the mean was used to compare the control tests and tests which were loaded with a spring to reduce fluctuations. The measurements from these two groups of tests showed that when the ploughs were loaded with a spring the mean had less variation than the control tests.

■■

NEWS

The 17th CIGR World Congress 2010

Québec, Canada, 13-17 June 2010
http://www. bioeng.ca/Events/CIGR/index.htm

The International Commission of Agricultural Engineering (http://www.ucd.ie/cigr/) will hold its 17th World Congress in **Québec City, Canada, from 13-17 June 2010**. The Canadian Society for Bioengineering, *la Societé canadienne de génie agroalimentaire et de bioingé nierie* (CSBE/SCGAB), will be the host Society (http//www.bioeng.ca/).

The theme of the Congress is 'Sustainable Biosystems through Engineering'. The local organising committee is planning several exciting events that will make your stay in Québec City a truly memorable one. Québec is one of the oldest cities in North America, celebrating its 400th anniversary in 2008. Eastern Canada offers excellent opportunities for technical, historical and natural science exploration. Plan to share your most recent discoveries in the areas of agricultural, food and biosystems engineering with colleagues from around the world. Mark the dates (l3-17 June 2010), so you can participate in the progress and development of the trends in your field.

More detailed information about the 17th CIGR World Congress 2010 will appear on this site in the near future.

You may also contact the following persons:

Chair of the local organizing committee
Dr. Stéphane Godbout, ing., agr.
Institut de recherche et de développement en agroenvironnement
Stephane.godbout@irda.qc.ca

Chair of the scientific program committee
Dr. Philippe Savoie, ing., agr.
Agriculture and Agri-Food Canada
savoiep@agr.gc.ca

CIGR International Conference 2012

Some societies had submitted applications to host the CIGR International Conference 2012 and the offers were discussed at the CIGR meeting in Glasgow. The host will be determined at the CIGR International Conference in Rio in 2008.

18th CIGR World Congress 2014

September 2014, Beijing, China

Sponsors

The sponsors of the CIGR World Congress 2014 will include many international and national organizations engaged in agricultural engineering. The proposed sponsors are as follows:

- International Commission of Agricultural Engineering (CIGR)
- Chinese Society for Agricultural Machinery (CSAM)
- Chinese Society of Agricultural Engineering (CSAE)

Co-sponsors

- China Association of Agricultural Machinery

Manufacturers

- China Food and Packaging Machinery Industry Association
- Local government offices and local, regional and international associations, societies and institutions engaged in agricultural engineering, which will be included later.

Organisers

- Chinese Academy of Agricultural Mechanization Sciences (CAAMS)
- Chinese Academy of Agricultural Engineering (CAAE)
- China Agricultural University

Topics

- Land and water engineering
- Farm buildings, equipment, structures and environment
- Equipment engineering for plant pro-

duction

- Rural electricity and other energy resources
- Management, ergonomics and systems engineering
- Post-harvest technology and processing engineering
- Information systems

The detailed programme will be finalised later by the respective CIGR sections.

Tine and venue

September 2014, Beijing

Since the 2008 Olympics will be held in Beijing, more convention centres and hotels with excellent facilities for holding large-scale meetings will be made available. Many more options will become available according to the scale and activities of the Congress.

Message from the Chair of SEAg & the Scientific Committee and Information for the Society for Engineering in Agriculture 2009 International Conference

September 2009, Brisbane, Queensland, Australia
http: //www.ncea.org.au/seag/seag.htm

Pre-Release Notice

Dear Conference Delegates,

I hope you all returned safely to your Institutes/Universities and are busy getting back to your normal work routine. SEAg also hopes that while you are getting back to normality, you will occasionally 'gaze in the distance' and remember the good times you had during the recent Adelaide SEAg Conference!

(Society for Engineering in Agriculture 2007 National Conference, Agriculture and Engineering Challenge Today, Technology Tomorrow, 23-26 September 2007, Adelaide, South Australia)

I would like to thank everyone for making the effort to attend, especially our overseas colleagues who travelled many miles to join us at the Conference.

On a professional level, we certainly had a very informative conference (thanks to the tireless work of the members of the Conference committees, including Darren, Chris, Tim, Erik, Richard, Guang and Paul), but I also sensed that people had a good time socially as well. That is a highly important aspect of a successful event, as networking is very much a part of the 'Conference experience'.

Given the fact that (we believe!) everyone had a good time, we look forward to seeing you again in Queensland in 2009. Please promote the event at your respective organisations by using the attached 'preliminary notice'.

During the conference, we elected a new National Committee and I am certain that we will see a renewed sense of enthusiasm and thus, a greater number of activities within the Society in the next few years. As a member (or supporting member) of the Australian Agricultural Engineering Society (SEAg) I would like to invite you to take ownership of our organisation and participate in the planning and execution of future SEAg activities, including the 2009 Conference.

In the meantime, if you have any comments, suggestions and/or questions, please do not hesitate to contact me or any of my colleagues on the National Committee.

Best regards

PS: If you have any pictures you would like to share, please send them to Dr Chris Saunders (chris.saunders@unisa.edu.au), so we can post them on the conference website for everyone to enjoy!

Dr. Thomas Banhazi (Senior Research Scientist), Chair - Smg and ScientiPc Committee (2009)

South Australian Research and Development Institute, LSA Roseworthy Campus, University of Adelaide, Roseworthy SA, 537 1 Australia

Tel.: +61 (08) 8303 7781, Fax: (08) 8303 7975 or (08) 8303 7689

VIII CLIA 2008
VIII Latin American and Caribbean Congress of Agricultural Engineering

7- 9 May, 2008, Managua, Nicaragua
www.clia2008.uni.edu.ni

The VIII CLIA will be held in Managua, Nicaragua from 7 to 9 of May, 2008.

Papers in Spanish, Portuguese or English will be accepted

Subject areas:

Soil and water engineering; power and machinery; Food and process engineering; Agric. structures and environment; energy in agriculture; biosystems engineering; information technology; agricultural engineering education, regional agriculture integration

Important deadlines:

Submission of abstracts: Before January 15, 2008

Full paper: March 30, 2008

For any further information, please contact:

Ing. Horacio Gonzalez

at: horaciogonzalez1961@hotmail.com

Dr. Efraim Chamorro at: echamorro@uni.edu.ni

Prof Omar Ulloa, President Latin, American and Caribbean Society of Agricultural Engineering (ALIA)

ASABE 2008 Annual International Meeting

29 June-2 July
Providence, Rhode Island, USA
http://www.asabe.org/meetings/aim2008/index.htm

The technical sessions at the meeting are divided into the following subject areas:

BE = Biological Engineering, INTL = International, EDU = Education, PM = Power & Machinery,

ESH = Ergonomics, Safety & Health, SW = Soil & Water, FPE = Food & Process Engineering,

SE = Structures & Environment, IET = Information & Electrical Technologies, T = Other Areas

Division Programme Chairs

Vice Chair & Other - Adel Shirmohammadi

Biological Engineering - Yanbin Li

CSBE - Stefan Cenkowski

Education - S. Andy Hale

Ergonomics, Safety & Health - Gary T. Roberson

Food & Process Engineering - Parameswarakum Mallikajunan

Information & Electrical Teclmologies - Robert S. Freeland

International - Israel S. Dunmade

Power & Machinery - Larry J. Hoover

Structures & Environment - Ronaldo Maghirang

Soil & Water - Fadi Z. Kamand

Energy (T-1 I) - William W. Casady

Deadlines

15 November 2007, Presentation proposals due to ASABE headquarters

November 2007, Session organizers notify authors of acceptance

10th International Congress on Mechanization and Energy in Agriculture

14-17 October 2008 Antalya/Türkiye
http://www.akdeniz:edu.tr/ageng2008

CALL FOR ABSTRACTS!
Deadline: 25th January 2008

Dear Colleagues,

The Department of Agricultural Machinery, Faculty of Agriculture, Akdeniz University is organizing the 10th International Congress on Mechanization and Energy in Agriculture, 14-17 October 2008, in Antalya, Turkey. The aim of the Congress is to bring the researchers and experts working in many different areas of Agricultural Engineering and to discuss on going researches and also new teclmologies.

Keynote speakers of the congress are Professor Irenilza A. Naas, Professor Da-Wen Sun, Professor Rainer Horn and Professor K. C. Ting whose keynote speeches will be on the actual subjects.

Please submit your 300-word abstract to Assoc. Prof. Dr. Can Ertekin, Congress Secretary, by January 25, 2008, by e-mail, ageng2008@akdeniz.edu.tr

All abstracts will be notified about acceptance of their papers by 7th March 2008. Kindly be informed that the deadline for the full paper submission is 16th May 2008.

Prof. Dr. Osman YALDIZ, Chairman

AAAE News

9th International Agricultural Engineering Conference (IAEC) - 2007

The Asian Association for Agricultural Engineering (AAAE) organized a four day International Agricultural Engineering Conference (IAEC), the ninth in its series, at the AIT Conference Center, Bangkok (Thailand) during December 3-6. This biennial **ent, convened by **Prof. Vilas M. Salokhe**, was delegated by nearly 130 participants - representing over 25 countries. At the opening ceremony, introductory remarks were made by **Dr. H. P. W. Jayasuriya** - the Chair of the Conference Organizing committee. The AAAE President - **Prof. Nobutaka lto**, followed by **Mr. Yoshisuke Kishida** - the AAAE President-Elect delivered their welcome addresses. I had the honor of proposing Vote of thanks and availed the privilege of announcing the Executive Council election results and the winners of two AAAE awards.

The first AAAE-Sakai Science & Technology Award was conferred upon **Prof. Vilas M. Salokhe**. The AMA-Shin-Norinsha-AAAE Young Researcher Award was bestowed upon **Dr. Sreekala G. Bafwa**.

Executive Council - 2008

Mr. Yoshisuke Kishida (FM 003) - President
Prof. Ren Luquan (LM 074) - Vice President for Energy, Environment and Emerging Technologies
Dr. Arzhang Javadi (LM 149) - Vice President for Farm Machinery and Power
Prof. Silvio Kosutic (LM 043) - Vice President for Soil and Water Engineering
Prof, Hyun Jin Park (LM 145) - Vice President for Post Harvest and Biotechnology
Prof. Shujun Li (LM 123) - Vice President for Industry
Prof. Vilas M. Salokhe (FM 009) - Director of Communication and Public Relations
Dr. H. P. W. Jayasuriya (LM 064) - Treasurer
Dr. Peeyush Soni (LM 109) - Secretary-General and AAAE Newsletter Editor

New President Message

I wish you all happy and prosperous New Year 2008.

Asian region has never taken the higher position in the world than that of present. With more than 60 % of world population, China, India and ASEAN countries are enjoying remarkable economic growth, getting to be the center of world economy. Under such growing economy and population, we are faced with many problems with regard to food, water, farmland and environment. Especially the solution of energy problem caused by the rise of oil price is very important. The solution of those problems in Asian region means the solution of the same kind of the problems throughout the world. Taking it the other way we will fail to solve world problems if we are not able to find the solution to the problems in Asia. In finding the solution to those problems, the rote of agricultural engineering and related scientific technologies is very important. For example, corn price is getting higher since The U.S. announced new energy policy to promote bio-fuel last year. International corn price, which had been around US$2.00/bushd for a long time, has risen to over US$5.00/bushel. Production of bio-ethanol is causing the struggle between food and energy. About 20 % of the world corn production is from China, where the average yield is 5 tons per hectare, the half of the average yield in The U.S. In order to solve the problems over corn production, it is the key to increase average yield/hectare in China. Agricultural engineering technologies will be of great importance in carrying out this task. In finding solution to those historical problems, Asian countries, especially agricultural engineers, should join the efforts. Asian Association for Agricultural Engineering will take a very important role. I am pleased to work together with AAAE members in carrying out that historical task. Your stronger cooperation is welcome.

I am resolved to work together on the following issues:

1. Establish the link between each agricultural engineering society in Asian countries and AAAE. Organize summit meeting by leaders of each agricultural engineering societies in Asia and discuss the future cooperation.
2. Promote the involvement of industries to AAAE in order to activate the communication among universities, governmental institutions and industries.
3. Establish new section to promote research activities on information, environment, agricultural engineering technology economics and biomass utilization.
4. Vice-presidents in charge of each present section are expected to intensify the present activities in each section.
5. Appoint Prof. Vilas M. Salokhe, who has given the great contribution to AAAE for a long time, as the Director in-charge of Communication and Public Relations to make AAAE more active organization.
6. Strengthen cooperation with CIGR.

Let's join our hands so that AAAE can play an important role in making solution to the world problems.

Yoshisuke Kishida, AAAE President

■■

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I Haffar


N Hay


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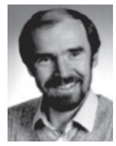
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