Tropical Agricultural Research Vol. 22 (3): 273 - 281 (2011)

Performance Evaluation of Four Wheel Tractor Driven High Capacity Combined Paddy Thresher

G.V.T.V. Weerasooriya, M.H.M.A. Bandara[1*] and M. Rambanda[2]

Postgraduate Institute of Agriculture
University of Peradeniya
Sri Lanka

ABSTRACT. *Lower performances of traditional threshing methods, labour shortage, reduced turn-around time and use of high yielding varieties have inevitably forced farmers to shift into mechanical grain threshing. Recently introduced four-wheel tractor driven high capacity combined paddy thresher gained popularity among Sri Lankan farmers. However, this thresher has not been properly evaluated. This study evaluated the field performances and economics of this thresher and monitored the emission of chaff and dust to compare the commercial makes, grain types and operational conditions. This study was carried out in the North Central Province of Sri Lanka, during the Maha season of 2008/2009. Air monitoring on inhaled air was done by filtration technique, using special masks and surrounding environment by gravity techniques, using Polyurethane foam. As per the RNAM test code procedures, three commercial makes of high capacity combined paddy threshers were evaluated under different operational conditions for long and short grain paddy varieties with two replicates. The combined paddy threshers showed 1.8% damaged grain, 0.2% blown grains, 1.6% grain losses, 96.7% threshing recovery, 98.8% threshing efficiency, 90.7% cleaning efficiency, 1178 kg/h corrected output capacity and Rs. 2744 actual cost of threshing per metric ton of output at 14% moisture content. Though this thresher is suited for Sri Lankan conditions, it is associated with considerable amount of chaff and dust content such as; 2.04 mg/cm^2/h in inhaled air and 35.59 mg/cm^2/h in surrounding environment. The performance, economics and chaff and dust emission vary with make of the machine, grain type and operational conditions. Grain moisture is the most dominantly affected factor for the thresher performance.*

Keywords: *Chaff, dust, paddy, threshing,*

INTRODUCTION

The Sri Lankan economy is primarily based on agriculture. Rice is the major food crop, plays a vital role in the economy and livelihood of people. Post-harvest losses of paddy in Sri Lanka is estimated at 15% of the total production (Fernando and Palipane, 1984), of this 24% of losses occur during the threshing and cleaning stages (IPHT, 2002), which is equivalent to 97,200 MT of paddy in the year 2007. This implies the need for technically efficient threshing practices.

Threshing operation which involves separation of paddy from panicles is one of the most important part of postharvest operations. Paddy threshing is a laborious task and becomes

* To whom correspondence should be addressed: mmabe@yahoo.com
1 Department of Agriculture, Peradeniya, Sri Lanka
2 Sub Campus, University of Peradeniya, Maha Iluppallama, Sri Lanka

more difficult during the inclement weather and labour shortage during peak seasons (Khushk and Lashari, 2006). With the introduction of new varieties and use of modern agronomical practices, the problems of threshing have increased over the recent past because of the greater amount of crop that has to be handled. Threshing of rice was mainly done by threading over harvested crop using buffalo or tractors in Sri Lanka.

Lower performances of traditional threshing methods, labour shortage, reduced turn-around time and use of high yielding varieties have inevitably forced farmers to shift into mechanical grain threshing. Among the several paddy threshers, the four wheel tractor driven high capacity combined paddy thresher which was introduced in year 2000 has gained popularity within a short period of time due to its higher threshing capacity.

This machine consists of throw-in type axial flow threshing system combined with an efficient air and oscillating screen cleaning system facilitated with re-circulated separating system. The combination of threshing cylinder and concave effectively separate the grain and convey the straw through and out of the machine. An oscillating screen and an air-blast blower provide additional separation of grain from the straw. Cleaned grain is conveyed to the bagging outlet by screw conveyor in CIC and Farmers thresher; in Hayleys (Agrotech) machine through grain pipe and trough (Fig. 1). The peg teeth on the threshing cylinder beat the material, separate the grain from the straw and at the same time accelerate them around the cylinder. The spiral louvers fitted to the upper concave move the material axially from the feed to the discharge end of the cylinder. The straw is discharged from the machine, through the delivery chute by the peddle-fan at the discharge end of the cylinder. Counter pegs on the lower concave assist in further threshing of the grain.

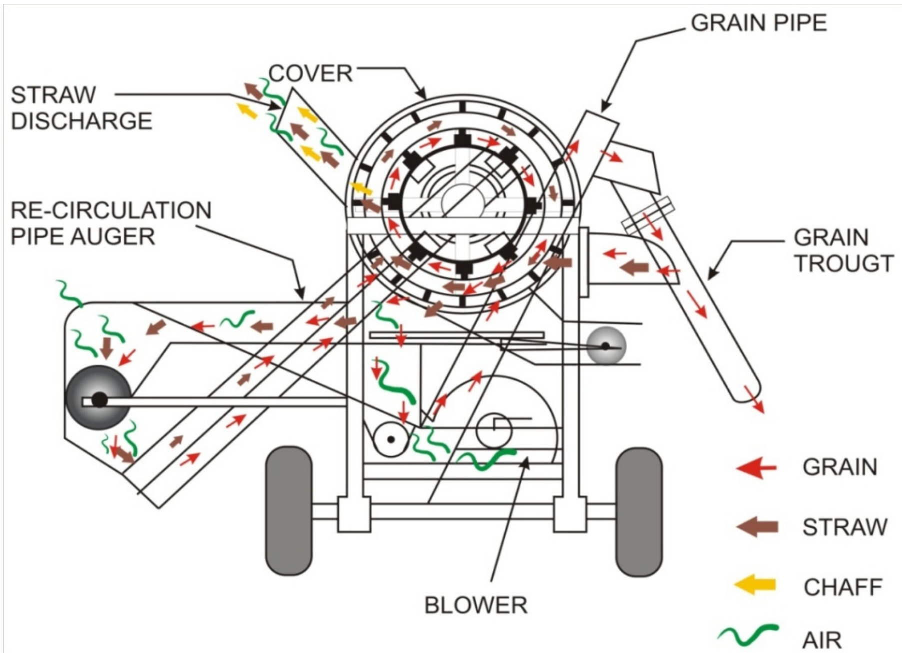

Fig. 1 Schematic diagram of high capacity combined paddy thresher operation
(Source: Operator's manual, Agrotech thresher machine)

This machine may cause low quality of grain due to crack formation which is not suited for seed paddy production, low shelf life and low marketing price. Further, a considerable amount of paddy is lost as un-threshed paddy. The other major defect of this machine is environmental pollution due to chaff and dust formation.

A proper evaluation on four wheel tractor driven high capacity combine paddy thresher has not been conducted in Sri Lanka, the availability of the technical information about this machine is very low and difficult to answer the farmers' doubts on grain quality and losses. Further, without monitoring environmental pollution conditions, it is difficult to find technical remedies to avoid them.

The objectives of this study was to evaluate the field performances and economics of this thresher and monitor the emission of chaff and dust to compare the different commercial makes of thresher, with different grain types at different operational conditions.

METHODOLOGY

Study was carried out in the North Central Province of Sri Lanka, during the *Maha* season of 2008/2009. Twelve field sites were purposely selected, considering two rice grain types namely; long, short and commonly used three makes of four wheel tractor driven high capacity combine paddy threshers namely, Chemical Industries (Colombo) Limited (CIC), Hayleys (Agrotech), and Farmers (6 treatments, 2 replicates). Extent of the each site was one acre or more.

Prior to the evaluation, test condition of crop (variety, duration of crop, grain ratio, grain moisture content, straw moisture content, percentage of cracked grain and insect damaged grain) condition of machine and operation (rotational speed of tractor engine and threshing drum), and ambient condition (wind velocity) were determined.

The filtration technique was used to monitor the chaff and dust in inhaled air (Dara, 2005). The accumulated weight of chuff and dust on the special masks worn by the operators was used as an indicator of chaff and dust content of the inhaled air. The gravity technique was used to monitor the chaff and dust content in surrounding environment (Dara, 2005). The accumulated weight of chaff and dust on the Polyurethane foam which were laid on surrounding area was used as an indicator of chaff and dust content of the surrounding environment.

The evaluation was carried out as per the Regional Networks for Agricultural Machinery Economic and Social Commission for Asia Pacific (RNAM), 1995 test codes and procedures. First, the thresher was allowed to run for a short period of time. This time was required to make adjustments to the working parts and feeding methods, and for filling the residual seed amount remain in the thresher. The field performances of the threshers were evaluated by varying thresher drum speeds as follows: (1) normal (usual speed of the operator) and (2) recommended (650 rpm), as reported by, Chirnaksorn *et al.* (1990), and the recommendation of manufactures. At that speed, the PTO shaft rotate at 540 rpm which gives the maximum power output of category II type tractors and the thresher drum, at optimum peripheral velocity (14 - 15 ms^{-1}) for *Indica* type paddy varieties (Gummert *et al.*, 1992). The speed was set by tractor engine throttle. Paddy bundles with different weights (50 kg, 100 kg, 150 kg, and 200 kg) were fed to the machine maintaining the maximum feeding rate of the skilled feeders.

Actual operating time for each of the test was measured by using a stopwatch. While operating the thresher, released materials at three outlets (main grain outlet, chaffed straw outlet, and immature grain outlet) were collected by using gunny bags and large canvasses, respectively. The straw portion was removed manually from the outlet materials. The material collected at three outlets, which indicates good grains, branches and broken were weighed separately by using a top loading balance. Receptive samples were extracted by using a sample divider and the sent to the laboratory for analysis.

In the laboratory, cracked grains were analyzed by using laboratory crack detector and impurities by using laboratory sieves. At first, all of the samples were weighed and separated manually for (1) whole grain (mature unbroken grain), (2) damaged grain (threshed grain which is are broken and de-hulled), (3) foreign matters (inorganic and organic material other than grain which includes sand gravel, clay, mud, metal chip, chaff and straw, weed, weed seed and other grains) and (4) un-threshed grain (whole grain attached to straw after threshing).

From the analysis of sample and actual operating time for each sample, the feed rate of crop, output capacity (the weight of the whole and damaged grain received per hour at main grain outlet), percentages of whole grain, damaged grain, foreign matter, and un-threshed grain at all outlets were calculated.

As per RNAM test code procedure, corrected output capacity; output capacity at standard conditions (grain moisture content 14% and grain ratio 0.5), Percentage of damaged grain at all outlets, blown grains and grain losses, threshing recovery (Ratio of the threshed grains at main outlet and the total grain input expressed as percentage by weight), threshing efficiency (Ratio of the threshed grain received at all outlets and the total grain input expressed as percent by weight), and cleaning efficiency (Ratio between the whole grain and the total output at main grain outlet expressed as percentage by weight), were calculated. The cost of threshing per metric ton of output at 14% moisture content was calculated using corrected output capacity and machine hire with labors.

Collected data were summarized using the average values. Significant variables at 0.05 level of significance (α) were selected by fitting analysis of variance (ANOVA) models using GLM procedure of SAS software. Least Square Mean (LSMEANS) separation was used to separate means of significant variables. Effects of covariates were identified by fitting linear regression models.

RESULTS AND DISCUSSION

The average values of the observed test conditions were 39.46 cm length of harvested crop, 0.633 grain ratio, 20.27% grain moisture content, 31.96% straw moisture content, 0.865% cracked grain, 1.148% insect damaged grain and 2.69 ms^{-1} average wind velocity. It seems that the used moisture content of paddy was relatively higher which causes to the lower machine performance. It is due to the present day farmers' practice as threshing paddy just after the cutting or reaping. Best performances could be obtained with a crop which has been sun dried for 2-3 days, until moisture content reaches 18%.

Significantly affected variables and covariates at 0.05 α level to each of the parameters on chaff and dust emission, machine performances and economics are given in Table 1. Least Square Mean (LSMEAN) separation of significant variables and effect of significant covariates are shown in Tables 2 and 3, respectively. The average chaff and dust content in the inhaled air (2.04 $mg/cm^2/h$) were significantly affected by grain and straw moisture content showing negative relationship. This is due to the fact that higher moisture content of plant biomass causes reduction in the formation of dust and chaff. The average chaff and the dust content in the surrounding environment (35.59 $mg/cm^2/h$) were significantly affected by the machine type, grain type, grain moisture content and feeding rate. Grain moisture content and feeding rate showed negative and positive relationship, respectively. This is due to the moisture content which causes reduction in the chaff and dust emission and high feeding rate, more materials passing though the machine and producing more chaff and dust. Relatively higher content of chaff and dust were observed in the inhaled air of operators who worked at ground level and at the left side of surrounding environment where straw outlet is directed.

Operators are used to run this thresher at lower speeds (560 rpm average thresher drum speed) than the recommended because threshing charges are based on time. Average percentage of damage grain at all outlets (1.802) was not significantly affected by machine type, grain type, rotational speed of thresher drum, grain and straw moisture content and crop feeding rate. Percentage of blown grains in average (0.159) was significantly affected by machine type and thresher drum speed. Lower percentage of blown grain was recorded at recommended drum speed due to the highest efficiency of grain separators of that speed. Average percentage of grain losses (1.638) were significantly affected by machine type, grain type, thresher drum speed, grain moisture content and crop feeding rate. Lower percentages of grain losses were shown at normal speed of the thresher drum. The increase in cylinder speed due to the increasing of the impact force exerted by the threshing drum to detach the paddy grains from the ear heads which is reflected in the increase of breakage was the reason. Grain moisture content and crop feeding rate showed a significant positive relationship. Kradangnga (1982), Ichigawa and Sugiyama (1986) also reported the same relationship between feeding rate and grain losses. In the higher feeding rates, a thick layer of material between thresher drum and concave occurred. This lowered threshing action, grain separation and increased scattered losses accessing higher percentage of grain losses. At the same time higher grain moisture content also caused to higher brakeage of grains. Threshing recovery of 96.691% was significantly affected by grain type, grain moisture content, straw moisture content and crop feeding rate. Grain moisture content, straw moisture content and crop feeding rate showed negative relationship with the threshing recovery which was due to higher moisture contents of straw and grain causing higher percentage of damaged grain and clogging conditions. Tandon *et al.* (1988) also reported the same result. Higher feed rate or through-put provide less chance to panicles to hit against an individual teeth of cylinder and eventually get less contact time and increase the un-threshed percentage of paddy.

Thresher drum speed and grain moisture content were the significant variables and covariate for threshing efficiency of 98.81%. When compared with the results indicated by Fernando and Palipane (1984), this machine showed higher threshing efficiency than the buffalo and tractor threading and lower threshing efficiency than the axial flow threshing. The significantly higher threshing efficiency was shown at the recommended (higher) speed of the thresher drum. Higher threshing speeds increased the impact force exerted by the threshing drum to detach every paddy grain from the ear heads, gaining higher threshing efficiencies. The grain moisture content showed a significantly negative relationship due to the low efficient threshing action with increasing grain moisture content. Same result was reported by Tandon *et al.* (1988): threshing efficiency significantly increased with cylinder speed at 5% α level and the grain moisture content has a significant effect on threshing efficiency and grain damages at 1% α level. The cleaning efficiency of 90.67% was not significantly affected by machine type, grain type, rotational speed of drum, grain and straw moisture content and crop feeding rate. Corrected output capacity (1177.69 kg/h) was significantly affected by Machine type and grain type, grain moisture content, straw moisture content and crop feeding rate. This value is higher than the buffalo threading and axial flow threshers and lower than the tractor treading when compared with the result reported by Fernando and Palipane (1984). The result also stated that the drum speed not significantly affected the output. Chirnaksorn *et al.* (1990), reported contradictory results which the capacity increased as the drum speed and feeding rate increased. Chukuwa (2008) reported that grain type and feeding rate significantly affect to the output capacity of the rice threshers evaluated supporting the result of this study. Grain and straw moisture content showed significantly negative relationship while crop feeding rate showed a significantly positive relationship with corrected output. Increased moisture content of grain and straw caused to higher percentage of damaged grain losses, clogging conditions and lower output capacity. Similar result was reported by Tandon *et al.* (1988). But increasing feed rate course to increasing output capacity due to increasing intake.

Table 1. ANOVA for the evaluation performances (Probability values)

Evaluation Performance	Variables			Covariates		
	Machine type	Grain type	Thresher drum speed	Grain moisture content	Straw moisture content	Crop feeding rate
Chaff and dust in inhaled air	0.11	0.42	0.83	0.01*	0.01*	0.20
Chaff and dust in surrounding env.	<.00*	<.00*	0.80	<.00*	0.30	0.00*
Damaged grain %	0.55	0.21	0.07	0.60	0.75	0.69
Blown grain %	<.00*	0.30	0.00*	0.36	0.31	0.82
Grain losses %	0.01*	0.02*	0.03*	0.03*	0.22	<.00*
Threshing recovery %	0.28	0.00*	0.46	0.00*	0.02*	<.00*
Threshing efficiency %	0.42	0.13	0.05*	0.04*	0.13	0.08
Cleaning efficiency %	0.15	0.35	0.21	0.10	0.10	0.07
Corrected output	0.00*	0.00*	0.10	0.00*	0.00*	<.00*
Cost of threshing	0.00*	0.00*	0.10	0.00*	0.00*	<.00*

*Significant difference at 0.05 α level

Table 2. LSMEAN separations for the significant variables

Evaluation	Commercial makes			Grain Types		Drum Speed	
Performance	CIC	Farmers	Agrotec	Long	Short	Normal	Rec.
Chaff and dust in surrounding env.	34.84^{a}	55.22^{b}	16.72^{c}	46.12^{p}	25.07^{q}		
Blown grain %	0.076^{a}	0.102^{a}	0.298^{b}			0.189^{x}	0.129^{y}
Grain losses %	0.802^{a}	1.547^{ab}	2.566^{b}	0.841^{p}	2.436^{q}	1.183^{x}	2.093^{y}
Threshing recovery %				98.224^{p}	95.158^{q}		
Threshing efficiency %						98.615^{x}	98.997^{y}
Corrected output	1244.55^{a}	957.66^{b}	1330.85^{a}	982.14^{p}	1373.24^{q}		
Cost of threshing	2591.30^{a}	3237.06^{b}	2404.47^{a}	3270.11^{p}	2218.44^{q}		

Mean values with same letter are not significantly different at 0.05 α level

Table 3. Effects of significant covariates (Regression coefficients)

Evaluation performances	Grain moisture content	Straw moisture content	Crop feeding rate
Chaff and dust in inhaled air	-1.203	-0.491	
Chaff and dust in surrounding environment	-2.504		0.048
Grain losses %	0.194		0.001
Threshing recovery %	- 0.247	- 0.082	- 0.001
Threshing efficiency %	-0 .055		
Corrected output	-39.514	- 0.498	0.102
Cost of threshing	15.244	0.482	-0.110

The average labor requirement for threshing per ton of output at 14% moisture content was 3.86 man-hours. When compared with results reported by Fernando and Palipane (1983), this machine utilizes lower labour than other threshing methods present in Sri Lanka. The hiring charges of this thresher, including tractor and labourers, varied from Rs. 3000 – 3200/h. Average cost of threshing per ton of output at the 14% moisture content was Rs. 2744.28.

When compared to the manufactures' specifications, similar performances were observed on grain losses, threshing efficiency and lower performances on corrected output capacity (Anon, no date and Mongkoltanatas and Opannukul, 2004). Based on the ANOVA results given in Table 1, Commercial makes of the machine, type of grain and grain moisture content are the most dominant variables and covariates for the chaff and dust emission. Lower chaff and dust emission is recorded for the short type grains than long grain types. Commercial makes of the machine, type of grain, thresher drum speeds and grain moisture content are the most dominant variables and covariates for better performances of the machine. Higher machine performances are recorded for long grain type compared to short grain types. Relatively higher machine performances are recorded in recommended thresher drum speed. Commercial makes, type of grain, grain moisture content, straw moisture content and crop feeding rate are the significantly affecting factors on threshing cost. Short grain type shows significantly lower threshing cost than long grain type. Grain moisture content is the most dominant factor for overall machine output. Hence it is recommended to use the crop with optimum grain moisture content (18%) to achieve higher evaluation performances.

CONCLUSIONS

The four wheel tractor driven high capacity combined paddy thresher worked satisfactorily with higher moisture content of crop and showed relatively higher average performances (some of them are reached to the test condition), without vibration, clogging or any other deficiencies; in comparison to other methods and therefore it is suited to the Sri Lankan condition.

The simple and low cost air monitoring methods which were used in this evaluation appeared to be successful for monitoring of particulate type air pollutants such as chaff and dust. It is observed that the average chaff and dust content of operators' inhaled air and surrounding environment were 2.04 $mg/cm^2/h$ and 35.59 $mg/cm^2/h$, respectively. Hence considerable level of air pollution was associated with the use of this combined paddy thresher.

The results of this study revealed that, there was a considerable level of chaff and dust accumulation on operators' inhaled air and also in the surrounding environment. Therefore some structural modifications to the machine should be introduced to minimize the above condition. Interpreting the results of performance test of combined thresher, it implied to some degree that the mechanism of the thresher was quite effective and appropriate. The aspect to be considered towards the machine development should be to partial modification in order to improve the threshing efficiency, output capacity, and lowering the cost of threshing. The performance variation on grain type could be minimized through proper adjustment of the machine. Hence the operators' awareness on adjustment should be improved through field demonstrations.

ACKNOWLEDGEMENT

Rajarata University of Sri Lanka, for providing the funds and Postgraduate Institute of Agriculture, University of Peardeniya for giving me the opportunity to make this research project a success. Institute of Postharvest Technology, for the assistance in laboratory analysis.

REFERENCES

Anon. [no date]. Operator's manual, Agrotech thresher machine. Thailand, Talaythong Factory Co., Ltd.

Chirnaksorn, S., Eam-o-pas, K., Kradangnga, P and Suwancahewakorn, P. (1990). Testing and evaluation of rice thresher. Kasetsart J. (Nat. Sci. Suppl.). Vol. 24. 69 – 79.

Chukwu, O. (2008). Performance evaluation of locally manufactured rice thresher in Niger state. Journal of Engineering and Applied Sciences. 3(7), 602-606.

Dara, S.S. (2005). A textbook of environmental chemistry and pollution control. 8th Edition. New Delhi: S. Chand & Company Ltd, India.

Department of Agriculture (DOA) (2006). Peradeniya, Sri Lanka. [on line]. [Accessed 22 February 2008] Available at http://www.agridept.gov.lk/agri_technologies_old.php?heading=Rice.

Economic and Social Commission for Asia Pacific Regional Networks for Agricultural Machinery. 1995. RNAM Test Codes and Procedures for Farm Machinery, Technical Series no: 12. Bangkok: United Nations Industrial Development Organization.

Fernando, M.D. and Palipane, K.B. (1984). A comparative study on buffalo, tractor and mechanical threshing in Sri Lanka. Economic review. 10 September/October 6 – 10.

Gummert, M. Kutzbach, H.D. Muhlbauer, W. Wacker, P. and Quick, G.R. (1992). Performance evaluation of an IRRI axial-flow paddy thresher. Agricultural Mechanization in Asia, Africa and Latin America. 23(03) 47–54.

Ichikawa, T. and Sugiyama, T. (1986). Development of a new combine equipped with screw type threshing and separating mechanisms. Tropical Agriculture Research Center. Japan. Reprinted from *JARQ* 20 (1), 31 – 37.

Institute of Post Harvest Technology (IPHT) (2002). Technical report for paddy post-harvest losses. Anuradhapura, Sri Lanka.

Khushk, A.M. and Lashari, M.I. (2006). Returns on paddy threshing. *DAWN the internet edition.* August 14, Edited by Nasir, A. Pakistan: DAWN groups of News papers. [on line]. [Accessed on 27 March 2008]. Available at http://www.dawn.com/2006/08/14/ebr6.htm

Kradangnga, P. (1982). Efficiency improvement of grain thresher. Technical seminar paper, Agriculture Engineering Division, Ministry of Agriculture and cooperatives. 20 – 21 May 1982. pp. 33.

Mongkoltanatas, J. and Opannukul, W. (2004). Research and development of axial flow thresher manufacturing for export. Thailand: Agriculture Engineering Research Institute, Department of agriculture.

Tandon, S.K. Sirohi, B.S. and Sarma, P.B.S. (1988). Threshing efficiency of pulses using step-wise regression technique. Agricultural Mechanization in Asia, Africa and Latin America.19 (3), 55–57.