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Mini combine harvester-innovative machinery

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Abstract
Harvesting of paddy is one of the most important operations in paddy cropping system. During peak seasons due to the non-availability of labour, delay in harvesting of paddy and results in heavy losses. For minimizing the labour problems during peak harvesting seasons and to ensure timeliness operation an attempt was made to develop a conceptual model of mini combine harvester that will be able harvest paddy on the go while moving through the field. To carry out the desired function, the paddy harvester comprise of a cutting unit, conveying unit, harvesting unit and collection unit. The cutting unit cuts the paddy panicles above plant on ground surface. Conveying unit pick up the harvested material and convey it to threshing mechanism which threshes out grains from the plant due to its impact force and will allow them to fall into the collection unit. The harvested paddy will be collected in separate storage bin and unloaded.

Keywords: paddy harvester, cutting unit, conveying unit, storage bin

Introduction

India is one of the major producers of paddy in the world and paddy crop occupies an important place in the Indian agricultural economy. It is one of the most liked and consumed cereal crops in our country. The major paddy exporting nations are India, Thailand, and Vietnam. India had the highest export volume of paddy worldwide at 15.5 million metric tons as in 2020-21. Vietnam was the second largest paddy exporter, with about 6.4 million metric tons of paddy worldwide in this year whereas the largest paddy importers were the Philippines and China. In total of milled paddy amounted to approximately 496 million metric tons in 2020. Whereas, China consumed around 149 million metric tons of milled paddy per year and was the world's leading rice consumer in 2020. Following after China, India was ranked second with 106.5 million metric tons of paddy consumption in this year.

In India, Vidarbha were the eastern part of Maharashtra and geographical area of the Vidarbha region was found 9.72 Mha, out of which 4.98 Mha have been brought under cultivation of different crops. Total population of the Vidarbha region was 23.03 million which 23.74% of Maharashtra was. In Eastern Vidarbha Zone (EVZ) paddy based mono cropping system were followed and in Western part Soybean, Cotton, Pigeon pea based cropping system were followed. Paddy, the most important crop grown in EVZ as the climatic conditions are suitable for cultivation of paddy crop. In Maharashtra paddy crop was grown on 1.52 Mha with production of 4.02 MT and with productivity 2065 kg/ha. In Vidarbha region area under paddy cultivation was 0.79 Mha which was 51.68% area of Maharashtra under paddy cultivation. Production in Vidarbha region was 1.93 MT and productivity was 2.46 tones/ha (Krishisanwadini, Dr. PDKV, Akola 2021) [5].

Material and Methods

The main innovative objective of the study was to develop mini combine harvester which can harvest paddy crop from small fields of Vidarbha region of Maharashtra, India. Harvested paddy will be collected separately into the storage bin.

The tractor operated mini combine harvester was designed as a functional and experimental unit. The design of machine components were based on the principles of operations, selection of suitable metering device, standardization of speed, tested and compared with the conventional method, to give an appropriate shape in the form of prototype. The mechanical design details were also given with due attention, so as to give adequate functional rigidity for design of machine.

Following steps were followed while designing a mini combine harvester

a) Drawn sketch of the machine; located all the components, determined the size by using principles of machine design and strength of materials.
b) Estimated the cost of machine using available information about the cost of finished, semi finished, fabricated items, labor cost, overhead charges etc.
c) Predicted the performance of machine using field efficiency values of 70% and recommended operational speeds. The economic justification could be based upon its long usage or related to the overcoming the timeliness constraints and effect on yield in conjunction with other essential inputs.
d) Fabricated the prototype of mini combine harvester according to the design specifications.
e) Evaluated the performance of the prototype in laboratory and in actual field conditions for harvesting of paddy crop.
f) Modified the machine, as changes are required to achieve expected level of performance
g) Finalized the design.

General design consideration

A mini combine harvester for harvesting of paddy crop was designed by considering the market demand for machine by conducting surveys of existing harvesting practices, crops handled, implements/machine used and farmer's preferences.

A new design was initiated to provide a machine for paddy harvesting, with an improved design to overcome problems of existing machines. Forecast for the demand of such a machine as favorable, engineering design process was initiated and involved few selected farmers as cooperators.

The design of mini combine harvester consists of several steps and aquired basic information about the following:

a) Crops and their characteristics.
b) Soils and climatic conditions during harvesting seasons.
c) Agronomic requirements of crops and yield levels.
d) Sources of power available.
e) Labor requirements for harvesting.
f) Socio-economic conditions of farmers.
g) Size of holding.
h) Level of manufacturing skill at small finished components.
i) Ease of operation.
j) Calibration and maintenance.
k) Safety and operator's comfort.
l) Expected level of cost of machine and cost of machine operation.
m) Net benefit expected at farmer's level.

Fig 1: Developed mini combine harvesting unit

Result and Discussion

Table 5.37 shows the effect of interactions of variables *viz.* grain moisture - forward speed was significant, but interaction of grain moisture - cylinder speed and cylinder speed - forward speed were not significant. The interaction of grain moisture - forward speed - cylinder speed was also non significant. The cleaning efficiency was minimum at higher moisture content, forward speed and lower cylinder speed. Cleaning efficiency increased as the grain moisture content decreased from 22 to 18%. The cleaning efficiency increased as cylinder speed increased from 14 to 16 m s^{-1} at 18% moisture content. The results are in conformity with Sangwijit and Chinsuwan (2010), who revealed that higher grain moisture caused difficulties in proper screening because of poor flow of threshed material on sieve. The results are in conformity with Manes *et al*. (2015) who revealed that cleaning efficiency increased with increased cylinder speed and then decreased with further increase in cylinder speed as throughput increases in axial flow threshing system.

Table 1: Interaction between moisture content, forward speed and cylinder speed for cleaning efficiency in paddy

Grain moisture, (%)	Forward speed, (km h^{-1})			Grain moisture, (%)	Cylinder speed, (m s^{-1})			Forward speed, (km h^{-1})	Cylinder speed, (m s^{-1})		
	3.5	4	4.5		14	15	16		14	15	16
22	97.62	97.50	97.43	22	97.25	97.58	97.72	3.5	97.84	98.03	98.18
20	97.80	97.66	97.53	20	97.45	97.68	97.86	4	97.73	97.96	98.14
18	98.63	98.67	98.73	18	98.50	98.67	98.86	4.5	97.63	97.93	98.13

Table 2 revealed the ANOVA data of the cleaning efficiency which shows the effect of forward speed, cylinder speed and grain moisture content were significant at p= 0.05. The effect of interactions of variables *viz.* grain moisture - forward speed was significant, however grain moisture - cylinder speed and cylinder speed - forward speed were not significant. The interaction of grain moisture - forward speed - cylinder speed was also significant. The order of significance based on the F-values of these variables in descending order of the cleaning efficiency was -grain moisture, cylinder speed and forward speed. The F - value for the grain moisture content was the highest indicating that the moisture content had maximum effect on the cleaning efficiency.

Table 2: ANOVA for effect of grain moisture, forward speed and cylinder speed on cleaning efficiency in paddy

Source	Sum of Squares	DF	Standard error	Mean Square	F Value	p-value Prob > F	
Model	1.37	6	0.05	0.23	5.45	0.0212	Significant
A-Forward Speed	0.02	1	0.07	0.016	0.39	0.5532	
B-Moisture Content	1.19	1	0.07	1.19	26.54	0.0011	
C-Cylinder Speed	0.15	1	0.07	0.15	3.69	0.0964	
AB	2.500E-003	1	0.10	2.500E-003	0.060	0.8138	
AC	4.000E-004	1	0.10	4.000E-004	9.573E-003	0.9248	
BC	2.250E-004	1	0.10	2.250E-004	5.385E-003	0.9436	
Residual	0.29	7		0.042			
Lack of Fit	0.29	6		0.049			
Pure Error	0.00	1		0.000			
Cor Total	1.66	13					
Std. Dev.	0.20				R-Squared	0.8237	
Mean	97.92				Adj R-Squared	0.6726	
C.V. %	0.21				Pred R-Squared	0.1644	
PRESS	1.39				Adeq Precision	7.264	

**Significant at $p < 0.05$; ***Significant at $p < 0.0001$; DF: degrees of freedom

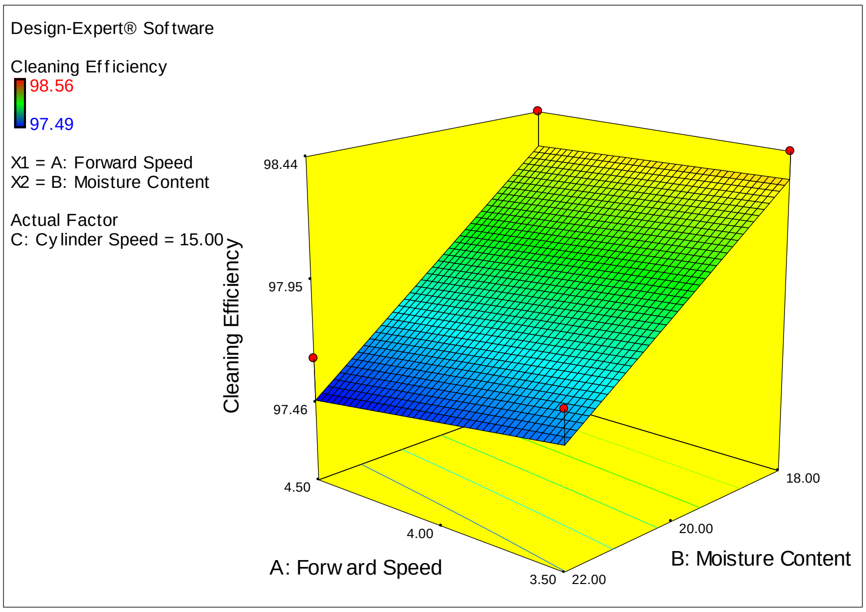

Fig 2: Effect of forward speed of mini combine harvester on cleaning efficiency at different moisture content in paddy

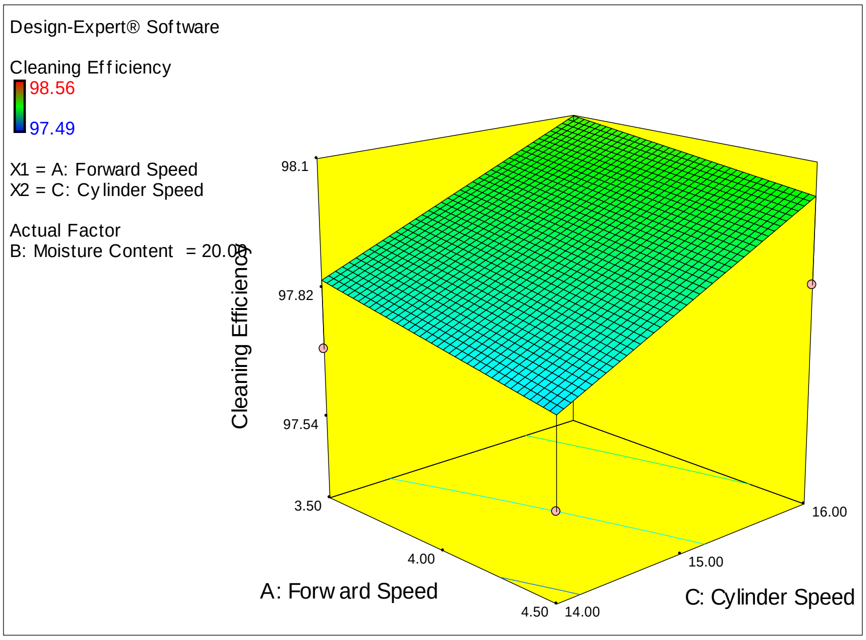

Fig 3: Effect of forward speed of mini combine harvester on cleaning efficiency at different cylinder speed in paddy

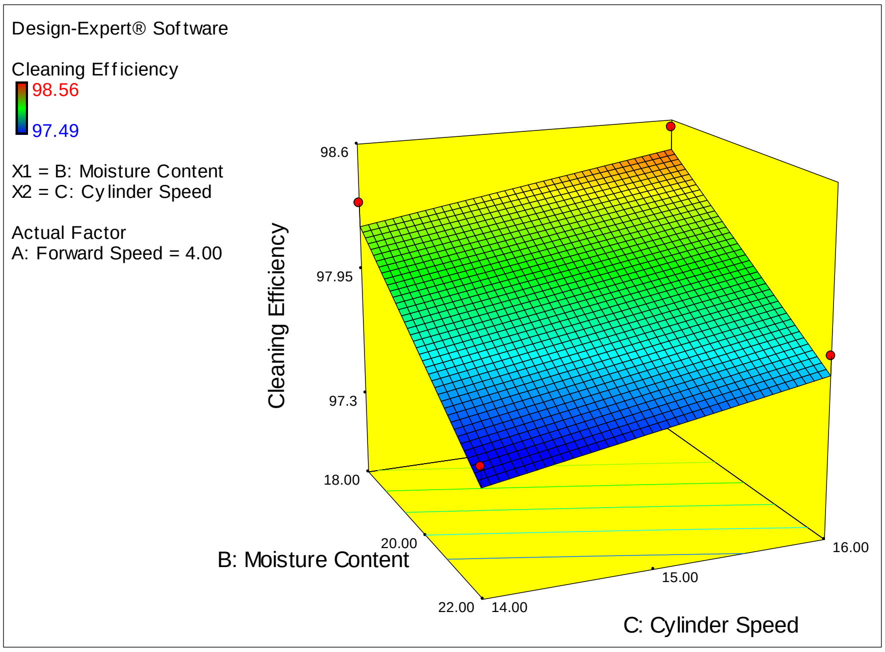

Fig 4: Effect of moisture content on cleaning efficiency at different cylinder speed in paddy

The data was quantified according to standards laid down and tabulated to draw meaningful inferences. The data for threshing efficiency, cleaning efficiency and grain losses were analyzed using a Randomized Block Design (RBD). ANOVA was calculated and the influence of each variables and their interaction were tested at 5% level of significance.

Keeping in mind the objectives of the present study, the effect of machine parameters *viz*., cylinder speed, forward speed and crop parameter *viz*., grain moisture content were studied in relation to threshing efficiency, cleaning efficiency and total grain losses for paddy varieties.

The mini combine harvester was tested at Instructional Farm of KVK, Gadchiroli for different machine parameters *viz*., cylinder speed 14, 15 and 16 m s^{-1}, forward speed 3.5, 4.0 and 4.5 km h^{-1} and crop parameter *viz*., grain moisture content 18 to 22% were studied in relation to threshing efficiency, cleaning efficiency and total grain losses for fine and coarse paddy varieties. Moisture content was found the most important factor influencing threshing efficiency, cleaning efficiency and total grain losses followed by cylinder speed and forward speed in paddy crop.

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