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Research Article

EFFECT OF THRESHING CYLINDER CONFIGURATION ON WHEAT STRAW QUALITY IN INDO-GANGETIC PLAINS

TIWARI R.K.*[1], SINGH Y.J.[2], DIN M.[3], CHAUHAN S.K.[4] AND NAMDEV A.[5]
[1]ICAR-Central Institute of Agricultural Engineering, Bhopal, 462038, Madhya Pradesh, India
[2]College of Agriculture, Central Agricultural University, Iroisemba, Imphal, 795004, Manipur, India
[3]ICAR-AICRP on UAE, Central Institute of Agricultural Engineering, Bhopal, 462038, Madhya Pradesh, India
[4]College of Agricultural Engineering and Post-Harvest Technology, Central Agricultural University, Ranipool, Gangtok, 737135, Sikkim, India
[5]ICAR-AICRP on UAE, Central Institute of Agricultural Engineering, Bhopal, 462038, Madhya Pradesh, India
*Corresponding Author: Email - rk96tiwari@gmail.com

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Abstract: The threshing on Indian farms is required to make and collect both grain and chaff for human and cattle consumption, respectively. This criteria of wheat bhusa making led to unacceptability of combines and the simultaneous development of threshers which not only separate grain but also deliver wheat straw in size of 10-20 mm length. The wheat straw size for maximum output capacity and maximum threshing efficiency were 22.43 mm and 22.67 mm at tip diameter of 600 mm and spike thickness of 6 mm corresponding to maximum feed rate (780 kg/h) in case of rectangular spiked and round spiked threshing cylinders. For higher threshing efficiency, fine straw quality and minimum specific power consumption, rectangular spiked threshing cylinder of 600 mm tip diameter and spike thickness of 6 mm have given best performance results with total grain loss within permissible limit. The spike thickness of 6 mm gave minimum broken grain loss with fine straw quality. The round spiked (plain spike) threshing cylinder with same configuration of threshing cylinder showed best results. But from mass manufacturing point of view, tip diameter of 600 mm and 8 mm round spike thickness will be appropriate for manufacturers. It also delivered good output capacity and threshing efficiency and fine straw quality.

Keywords: *Wheat straw, Output capacity, Threshing efficiency, Spike thickness, Tip diameter, Fine straw*

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Introduction

There is production of 112 million tonnes of wheat straw available in the country and by 2020, this quantity will increase up to 120 million tonnes, registering a growth of 6%. As per the projections, the share of UP in total wheat straw pool will be the highest (33%), followed by Punjab (19%), Haryana (15%), Rajasthan (11%), MP (10%) and Bihar (6%). The straw availability from other wheat producing states is 6% [1]. Three distinct operations can be identified within a threshing cylinder namely compaction, impact and shearing or rubbing. The crop receives only one impact at the entrance of the threshing cylinder, but is compressed repeatedly on its way to the exit [2]. It was reported that the quality of straw increased with increase in cross- sectional area of spikes. Analysis of straw size index indicated that the material retained on the sieves did not reflect directly the length of the straw. A sieve size index was developed for determination of straw quality by using different sizes of BIS sieves (square openings) in which the straw was made to pass by shaking on a sieve shaker. The material retained on each sieve, by weight, gave an idea about straw quality [3]. A cylinder of 610 mm diameter in power thresher was evaluated at 12-15% m.c. and 0.83 grain to non-grain ratio. They observed average length of straw of 17.07 mm at 8.89% m.c. and 99.5% threshing efficiency. The range of split straw and straw length varied 63.39 - 94.01% and 14.45 - 25.60 mm, respectively. Straw break up increased as the material became drier and was increased with increase in cylinder speed. Reducing the cylinder concave clearance had no great effect on straw break up [4]. A multicrop thresher was developed a with spike tooth cylinder and a fixed cylinder-concave clearance. This thresher resulted in wheat straw split of 25 to 30% of original length [5]. It was reported straw size of 14.45-25.1 mm and straw split of 63.39-94.01% at 8.89% moisture content and 99.49% threshing efficiency for threshing wheat using chaff cutter type thresher. At higher crop moisture content, grain breakage and power requirement were observed high and bhusa quality was poor [6]. The wheat straw length of 12.20 - 21.96 mm and straw split of 88.73 - 97.73 % were found during test trial on AAI spike tooth thresher of 3.7 kW capacity [7]. The serrated tooth type bruising system consumed lesser net specific fuel consumption as compared to the spike tooth type bruising system. In both the systems the straw quality observed was the same [8]. There was nil percentage of straw size more than 25 mm with the use of set of a worn-out pegs whereas the same was more than 13% while threshing wheat with the set of new pegs. The quality of bhusa was not adversely affected by the increasing peg wear [9]. The straw quality of wheat (HDM 4530 variety) during evaluation of 3.7 kW spike tooth thresher. The measure of straw quality was percentage of straw of 30 mm or lower size and that of the nodes. They recommended that straw larger than 30 mm and the nodes should not be more than 30% and 3 respectively. They found 89.1, 90, 92.5 and 95.7% of straw below 30 mm (by weight) at threshing cylinder speed of 550, 650, 750 and 850 mm, respectively. The nodes percent varied 4.9, 3.8, 3 and 2.7% at 550, 650, 750 and 850 mm, respectively [10]. A criteria was made for selection of threshing cylinder on the basis of quality of straw and power requirement per ton of crop. For wheat spike tooth type threshing cylinder required power requirement of 6-9 kW/t of crop and thresher gave fine straw quality [11]. The length of wheat bhusa was found to decrease with increase in cylinder and blower speeds and it also decreased with decrease in feed rate [12-14]. The objective of study is to identify and evaluate threshing cylinder configuration to obtain fine straw quality and quality grain product with minimum total losses, threshing efficiency and specific power consumption for wheat crop which is main crop in Indogangetic plains.

The independent parameters are shape of spiked threshing cylinder, tip diameter of threshing cylinder, thickness of the spike and feed rate. The dependent parameters are total grain loss, threshing efficiency, straw length of wheat, splitting of wheat straw, output capacity and specific power consumption.

Material and Methods

Arrangement of Teeth on the Thresher Drum

The development of a peg tooth drum with four cross bars and a two-pitch helical line over which the teeth are located [Goryachkin, 1968]. The direction of the helical path is given by the pitch.

$$t_p = a\,M$$

The teeth are placed at the points of intersection of the helical lines with the cross bars. When the drum rotates, each tooth moves in a particular plane.The number of adjacent planes in which the teeth move are given by

$$P = \frac{l_p}{a} + 1$$

The number of teeth which lie in the same plane of rotation is equal to the number of pitches of the helical path. The teeth on the concave are placed midway between the adjacent planes of rotation of the teeth on the drum.

Feed rate of Threshing Units

The plant mass entering the clearance between the drum and the concave of a thresher is carried over by the beaters and does not hamper the feed of the next portion (Lipovskii, 1998). Hence the feed rate can be expressed as

$$q = \Delta \eta \rho \mu_1 l \qquad (1)$$

where,

Δ= thickness of the plant mass layer at the entrance to the thresher,

l = length of the drum,

η = coefficient designating the utilization of the drum length,

μ= velocity of the plant mass entering the thresher and

ρ= density of the plant mass.

The thresher does not become clogged if the beater imparts an impulse force P. t to the fraction of the plant mass m1. This impulse force equal to or greater than the momentum m1 u1 which this portion had during its motion at the feed point of the thresher, that is

$$P\Delta t \geq m^1 \mu_1 \qquad (2)$$

Pneumatic parameters play an important role in cleaning performance. Air flow should be even across the width of the sieve. Air velocity should be set in relation to the grain throughput to maintain fluidization of the material. Three types of tests namely test at no load; test at load for short duration and test at load for long duration were conducted for threshing of crop. No load test was conducted at recommended speed for wheat crop threshing without any load for 10 minutes to observe the power consumption of the moving parts of the machine. The tests at load were conducted at maximum feed rate and recommended speed for wheat crop threshing. For each test, parameters related to crop, machine, operator and ambient conditions were recorded. The parameters related to the performance of the machine were also recorded. The speed of the moving parts was observed by a hand tachometer thrice during each test and average values were reported. The feed rates were determined by weighing crop samples of 25 kg each on a platform balance and keeping near the machine before the start of test. The maximum feed rate at which no checking of cylinder / blower / sieve occurred at recommended speed was determined initially and feed rate was controlled by regulating the quantity of the crop fed in pre-calculated time. For measurement of energy consumption suitable energy meter was used. The power consumption was observed several times by connecting suitable watt meter and the minimum, maximum and average readings were recorded. During each test three sets of samples were collected at 20 minutes intervals from main grain outlet (for 30 sec), sieve overflow outlet (30 sec) and blower outlet (15 sec) by using sampling bags and a nylon mosquito net. Stop watch was used for recording time. The grain and straw moisture were determined in accordance with IS:4333 (Part II). The total grain mixture collected at sieve underflow during one hour test were also analyzed before quality of bhusa was also analyzed by taking 500 g sample.

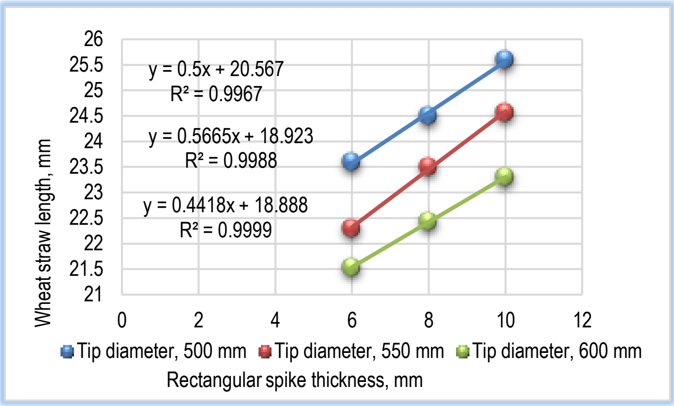

Fig-1 Relation of rectangular spike thickness with wheat straw length (feed rate 75 % of maximum)

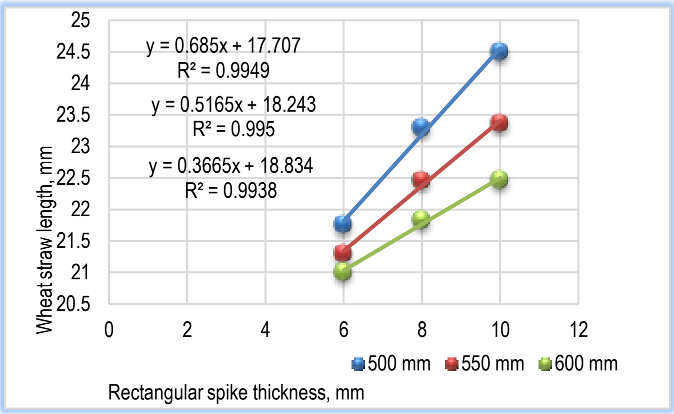

Fig-2 Relation of rectangular spike thickness with wheat straw length (maximum feed rate)

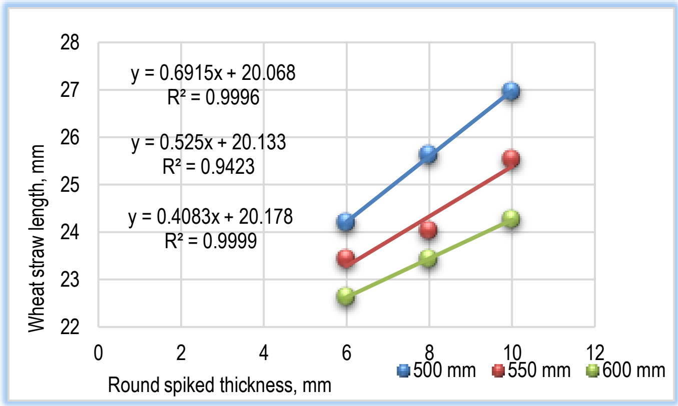

Fig-3 Relation of round spiked thickness with wheat straw length (feed rate 75 % of maximum)

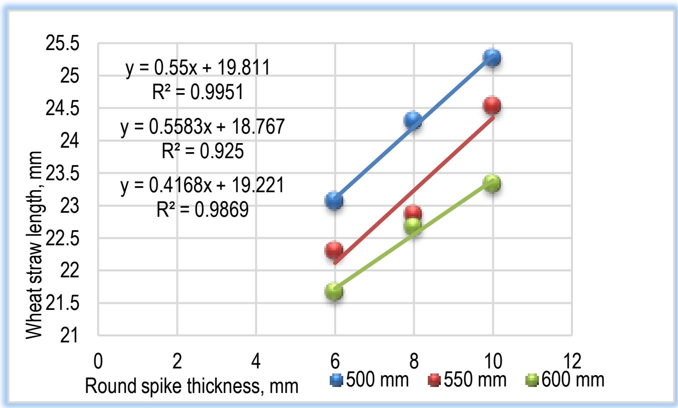

Fig-4 Relation of round spike thickness with wheat straw length (feed rate-maximum)

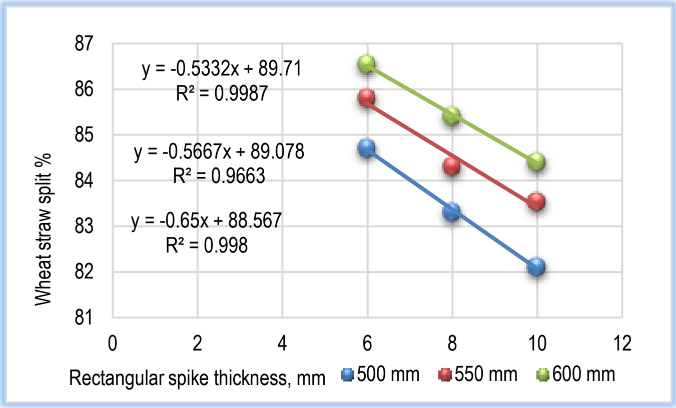

Fig-5 Relation of rectangular spike thickness with wheat straw split % (feed rate 75 % of maximum)

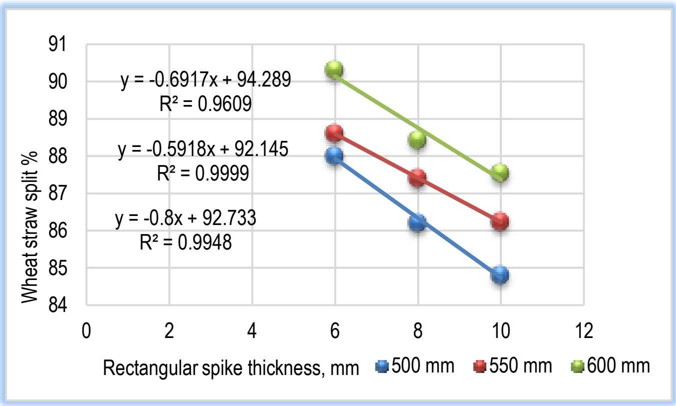

Fig-6 Relation of rectangular spike thickness with wheat straw split % (maximum feed rate)

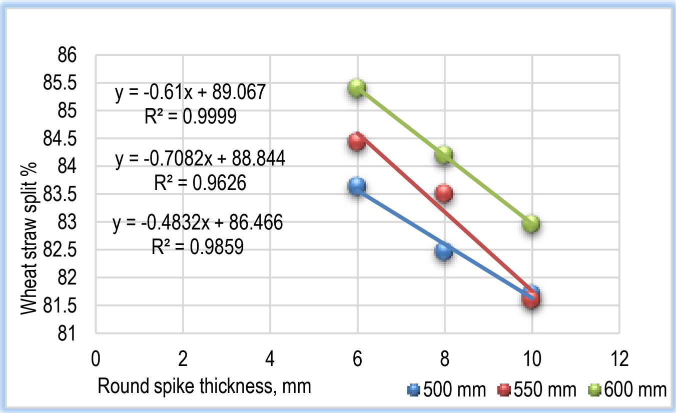

Fig-7 Relation of round spike thickness with wheat straw split % (feed rate 75 % of maximum)

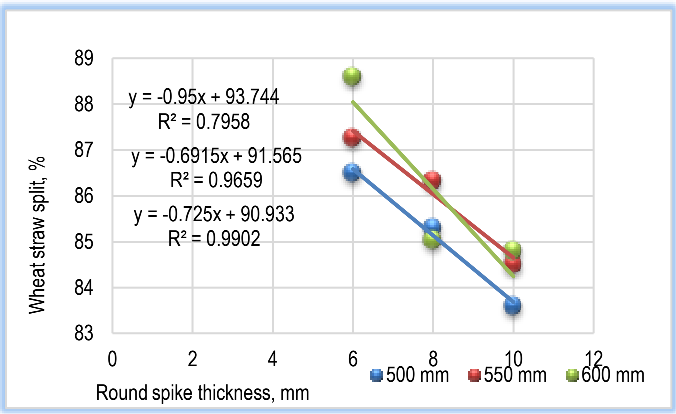

Fig-8 Relation of round spike thickness with wheat straw split % (feed rate-maximum)

Results and Discussion

Effect of Thickness of Spike on Length of Wheat Straw

The length of wheat straw increased with the increase in thickness of rectangular spike at 65% of maximum feed rate. The length of wheat straw was minimum (23 mm) at the tip diameter of 600 mm and rectangular spike thickness of 6 mm due to greater shear forces. The length of straw increased from 24.13 to 26.4 mm with increase in thickness of rectangular spike from 6 to 10 mm corresponding to the tip diameter of 500 mm which was due to reduced shear stress at greater thickness of spikes. As the thickness of spike increased from 6 to 10 mm, the length of wheat straw increased from 23 to 24.5 mm for the tip diameter of 600 mm. The reduced shear stress provided maximum length of straw of wheat (26.4 mm) at thickness of 10 mm and tip diameter of 500 mm. The coefficient of determination values varies from 0.9817 to 0.9989 which confirms the positive correlation of thickness of rectangular spike with wheat straw length at 65% of maximum feed rate. It is observed from [Fig-1] that length of wheat straw increased with increase in thickness of rectangular spike at 75% of maximum feed rate. The length of straw was minimum (21.533 mm) at the tip diameter of 600 mm and spike thickness of 6 mm due to more values of impact forces on crop mass at lesser thickness. There was increase in length of straw from 23.6 to 25.6 mm and from 22.3 to 24.566 mm with the increase in rectangular spike thickness from 6 to 10 mm for tip diameters of 500 and 550 mm respectively. As the spike thickness increased from 6 to 10 mm, the length of straw increased from 21.533 to 23.3 mm corresponding to tip diameter of 600 mm which was due to reduced impact forces at greater thickness of spikes. Maximum length of straw was 25.6 mm for the rectangular spike thickness of 10 mm and tip diameter of 500 mm. The coefficient of determination values is 0.9967, 0.9988 and 0.9999 which indicate that thickness of rectangular spike is positively correlated with length of wheat straw at 75% of maximum feed rate. It is seen from [Fig-2] that length of straw of wheat increased with increase in thickness of rectangular spike at maximum feed rate. The length of straw increased from 21.76 to 24.5 mm at the tip diameter of 500 mm and spike thickness varying from 6 to 10 mm which might be due to due to reduced shear stress at greater thickness of rectangular spike. Similarly, there was increase in straw length from 21.3 to 23.366 mm with increase of spike thickness from 6 to 10 mm at the tip diameter of 550 mm. Minimum length of straw was 21 mm at the tip diameter of 600 mm and spike thickness of 6 mm due to more impact forces at lesser thickness of rectangular spike. Maximum length of straw (24.5 mm) was for spike thickness of 10 mm and tip diameter of 500 mm which was due to reduced shear stress at greater thickness of spike. Higher values of coefficient of determination (0.9949, 0.995 and 0.9938) confirm that thickness of rectangular spike has positive correlation with length of straw at maximum feed rate. It is found that increase in thickness of round spike increased the length of wheat straw at 65% of maximum feed rate. The length of straw increased from 25.433 to 27.266 mm with increase in spike thickness from 6 to 10 mm at the tip diameter of 500 mm which was observed due to reduced shear stress at greater thickness of round spike. There was increase in straw length from 24.3 to 26.466 mm and from 23.566 to 25.3 mm with the increase in spike thickness from 6 to 10 mm corresponding to tip diameters of 550 and 600 mm respectively. Minimum wheat straw length was 23.566 mm for spike thickness of 6 mm and tip diameter of 600 mm which indicated smaller straw length due to more shear stress at lesser thickness of round spike. Higher values of coefficient of determination (0.9972, 0.9664 and 0.998) indicate that thickness of round spike has positive correlation with wheat straw length at 65% of maximum feed rate. The increase in effect of thickness of round spike increased wheat straw length at 75% of maximum feed rate as inferred from [Fig-4]. There was increase in length of straw from 24.2 to 26.966 mm with the increase in spike thickness from 6 to 10 mm at the tip diameter of 500 mm which was due to effect of reduced shear stress at greater thickness of spike. As the spike thickness increased from 6 to 10 mm, the straw length increased from 23.433 to 25.533 mm and from 22.633 to 24.266 mm corresponding to tip diameters of 8 and 10 mm respectively which was attributed to more shear stress at lesser thickness of spike. Minimum straw length was 22.633 mm for spike thickness of 6 mm and tip diameter of 600 mm. The values of coefficient of determination are 0.9996, 0.9423 and 0.9999 which confirm that thickness of round spike is positively correlated with wheat straw length at 75% of maximum feed rate. It is inferred from [Fig-5] that increase in thickness of round spike increased wheat straw length at maximum feed rate. The straw length increased from 23.066 to 25.266 mm with increase of spike thickness from 6 to 10 mm at the tip diameter of 500 mm due to reduction in shear stress at greater thickness of round spike. There was increase in wheat straw length from 22.3 to 24.533 mm and from 21.666 to 23.333 mm with increase in spike thickness from 6 to 10 mm corresponding to of tip diameters of 550 and 600 mm respectively which indicated reduced straw length for thinner spikes due to higher values of impact forces. Minimum wheat straw length was 21.666 mm at the tip diameter of 600 mm and spike thickness of 6 mm which was due to effect of more shear stress. The coefficient of determination values varies from 0.8403 to 0.997 which indicate positive correlation of thickness of round spike with wheat straw length at maximum feed rate. This is in conformity with the findings of [15].

Effect of thickness of spike on wheat straw splitting

It is observed that the increase in thickness of rectangular spike decreased wheat straw split percent at 65% of maximum feed rate. The wheat straw split decreased from 78.7 to 75.6% with increase in spike thickness from 6 to 10 mm at the tip diameter of 500 mm. There was decrease in wheat straw split percent from 79.9 to 76.633 and from 81.5 to 77.4% with the increase in thickness of spike from 6 to 10 mm corresponding to tip diameters of 550 and 600 mm respectively which was due to reduced shear stress for thicker spikes. Maximum wheat straw split (81.5%) was at 600 mm tip diameter and thickness of rectangular spike of 6 mm. The coefficient of determination values is 0.9446, 0.9735 and 0.9951 which confirm that wheat straw split is negatively correlated with thickness of rectangular spike at 65% of maximum feed rate. The increase in thickness of rectangular spike decreased wheat straw split percent at 75% of maximum feed rate as inferred from [Fig-6]. There was decrease in wheat straw split percent from 84.7 to 82.1% with the increase spike thickness from 6 to 10 mm at the tip diameter of 500 mm which yielded due to reduced shear stress. The wheat straw split percent decreased from 85.8 to 83.533% and from 86.533 to 84.4% with the increase in spike thickness from 6 to 10 mm corresponding to tip diameters of 550 and 600 mm respectively which was due to reduction in shear stress. Maximum wheat straw split was 86.533% at the 6 mm spike thickness and tip diameter of 600 mm due to more impact forces and shear stress. Higher values of coefficient of determination (0.998, 0.9663 and 0.9987) indicated the negative correlation of thickness of rectangular spike with wheat straw split percent at 75% of maximum feed rate. It can be seen from [Fig-7] that increase in thickness of rectangular spike decreased wheat straw split percent at maximum feed rate. The wheat straw split percent decreased from 88 to 84.8% and from 88.6 to 86.233% with the increase in thickness of spike from 6 to 10 mm due to reduced shear stress at greater thickness of spike. There was reduction in wheat straw split percent from 90.3 to87.533% with the increase in spike thickness from 6 to 10 mm at the tip diameter of 600 mm which yielded lesser split of wheat straw due to reduced shear stress. Minimum wheat straw split percent was 84.8% at the spike thickness of 10 mm and tip diameter of 500 mm due to lesser impact forces and reduced shear stress. Maximum straw splitting due to more shear stress was 90.3% at the 6 mm spike thickness corresponding to 600 mm tip diameter. The coefficient of determination varies from 0.9609 to 0.9999 which indicate that at maximum feed rate the effect of thickness of rectangular spike is negatively correlated with wheat straw splitting. The wheat straw split decreased with the increase in thickness of round spike at 65% of maximum feed rate. The wheat straw split percent reduced from 76.5 to 74.333% with the increase in spike thickness from 6 to 10 mm at the tip diameter of 500 mm due to reduced shear stress. Maximum wheat straw split percent was 80.3% at the tip diameter of 600 mm and spike thickness of 6 mm which was due to more impact forces and shear stress. There was decrease in wheat straw split percent from 79.533 to 76.8% and from 80.3 to 77.433% with increase in spike thickness from 6 to 10 mm corresponding to tip diameters of 550 and 600 mm respectively. This decline in wheat straw splitting was due to reduced shear stresses at greater thickness of spikes. The coefficient of determination values is 0.9993, 0.9572 and 0.8442 which confirm that thickness of round spike has negative correlation with wheat straw split at 65% of maximum feed rate. It is inferred from [Fig-8] that increase in thickness of round spike decreased the wheat straw splitting at 75% of maximum feed rate. The wheat straw split percent was maximum (85.4%) at the spike thickness of 6 mm and tip diameter of 600 mm due to higher values of impact forces and shear stress. There was decrease in wheat straw split percent from 83.633 to 81.7% with increase in thickness of spike from 6 to 10 mm corresponding to tip diameter of 500 mm, due to reduced shear stress. As the spike thickness increased from 6 to 10 mm, the wheat straw split percent reduced from 84.433 to 81.6% and from 85.4 to 82.96% corresponding to tip diameters of 550 and 600 mm respectively which were due to reduced shear stress at greater thickness of round spikes. Higher values of coefficient of determination (0.9859, 0.9626 and 0.9999) indicate that the thickness of round spike is negatively correlated with wheat straw split at 75% of maximum feed rate.

It is observed from [Fig-9] that increase in thickness of round spike decreased wheat straw splitting at maximum feed rate. Wheat straw split was maximum (88.4%) at the tip diameter of 600 mm and spike thickness of 6 mm due to more shear stress and impact forces. There was decrease in wheat straw split percent from 86.5 to 83.6% with increase in spike thickness from 6 to 10 mm for the tip diameter of 500 mm which was due to reduced shear stress at greater thickness of round spikes. As the spike thickness increased from 6 to10 mm, the wheat straw split percent decreased from 87.266 to 85.033% at the tip diameter of 550 mm which may be attributed due to reduced shear stress. There was decrease in wheat straw split percent from 88.4 to 85.8% with the increase in spike thickness from 6 to 10 mm at the tip diameter of 600 mm. The coefficient of determination values is 0.9902, 0.9659 and 0.7958 which confirm that thickness of round spike is negatively correlated with splitting of wheat straw at maximum feed rate.

Conclusion

The spike thickness of 6 mm gave minimum broken grain loss with fine straw quality. The round spiked (plain spike) threshing cylinder with same configuration of threshing cylinder showed best results. The minimum wheat straw length (21 mm) was achieved at maximum feed rate (780 kg/h) corresponding to tip diameter of 600 mm and rectangular spike thickness of 10 mm. The maximum wheat straw split percent (88.60%) was at 780 kg/h feed rate corresponding to tip diameter of 550 mm and rectangular spike thickness of 6 mm.

Application of research: Study of threshing cylinder

Research Category: Agricultural Engineering

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***Principal Investigator or Chairperson of research: Dr R K Tiwari**
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Research project name or number: Research station trials

Author Contributions: All authors equally contributed

Author statement: All authors read, reviewed, agreed and approved the final manuscript. Note-All authors agreed that- Written informed consent was obtained from all participants prior to publish / enrolment

Study area / Sample Collection: Indo-Gangetic Plains
Cultivar / Variety name: Wheat

Conflict of Interest: None declared

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.
Ethical Committee Approval Number: Nil

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