Print ISSN : 0972-8813
e-ISSN : 2582-2780

[Vol. 21(2) May-August 2023]

Pantnagar Journal of Research

(Formerly International Journal of Basic and Applied Agricultural Research ISSN : 2349-8765)

G.B. Pant University of Agriculture & Technology, Pantnagar

PANTNAGAR JOURNAL OF RESEARCH

Vol. 21(2) May-August, 2023

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A review on current scenario of paddy straw management machineries: Viable solution for in-situ residue management

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ABSTRACT: The agricultural residue mostly paddy residue is primarily regarded as a waste owing to its minimum utilization and discarding relating problems. Indian agriculture is progressively succeeding, more emphasizes is provided on the crop yield and productivity. But in existing situation, the management of bulk amount of post-harvest agricultural residue is cumbersome and onerous task and requires more momentum for its effective incorporation and utilization. With these implications, the farmers frequently compelled to opt for appropriate option of burning residues inopen farm field for getting good riddance from large quantity of paddy straw. To discourse these concerns, the in-situ post-harvest residue management machinery can prove to be a feasible alternative which not only provides judicious paddy straw management but also can restricts open field burning. These machineries are either based on the in-field retention or incorporation of crop residues. Recently developed machines *viz*., Happy seeder, Super seeder, Mulcher etc. plays an indispensable role in replenishing soil quality and reducing environmental pollution calumniating from stubble burning. These technologies supports in modifying soil physical properties, improving soil organic content and edaphic factors, provides economy to farmers, saving energy and consequently eradicating indiscriminate residue burning. The paper reviews the transformation and evolution in functional design and development of the paddy straw management machineries. It focuses on the previous developed technologies in the field straw management and its associated problems and issues.

Key words: Residue management, surface retention, surface incorporation, super SMS, happy seeder, super seeder

The Rice Wheat (RW) cropping system is mainly practiced on around 13.5 Mha across the Indo-Gangetic alluvial plains (IGP) of South Asia (NAAS 2007). This system is very forceful in providing food security to the people living adjoining this region. It also produces a large and bulk amount of post-harvest agricultural residues of wheat and paddy crops. The wheat residue has numerous applications in feeding and nourishing of animals as fodder but the paddy residue has maximum shortcomings and is mainly considered as a waste on account of its low food value for animals (the presence of silica content makes it less palatable for the domestic livestock). Hence, the generation of large amount of paddy residue creates its management and storage problems. Thereafter, the farmers have the only alternative to burn it in the field so that it will be easier for them to sow the next crop without any delay to affect the timeliness. Consequently, as it ensues, it is estimated that open field burning of about 23 million tons of rice residue every year in the north-western India. It is still the most convenient option for the farmers due to lack of user-friendly, cost- and time-effective alternative options to clear the fields for sowing of next wheat crop (NAAS, 2017). The paddy straw burning scenario is enumerated in Table 1.

The burning of residues contributes to atmospheric pollution that has serious human and animal health implications due to release of large amounts of air pollutants, and the loss of soil organic matter and

Table 1: Paddy straw burning in northern region of India

Particular	Punjab	Haryana	Western UP	Total
Area under paddy cultivation (Mha)	2.9	1	1.3	5.2
Area under Rice-Wheat system (Mha)	2.6	1.3	0.7	4.6
Paddy straw production (Mt)	22	7.5	4.4	33.9
Paddy residue burnt (Mt)	18.7	3	1.3	23

(Source: NAAS 2017).

plant nutrients during burning adversely affect soil health and sustainability of RW system (Yadvinder-Singh *et al.*, 2014). To ponder these major issues affecting the atmosphere and entire ecosystem, the technique of conservation agriculture involving the utilization of residue management machinery can prove to be resourceful and sagacious step over the ongoing traditional practices pertaining to burning. The residue retention as mulch and surface incorporation of mulch are the most imperative methods to replenish the agricultural and environmental sustainability. Therefore, this paper reviews the transformation and evolution in development of the paddy straw management machineries. It focuses on the previous developed technologies in the field of paddy straw management and its associated problems and issues.

Review of literature on development of technologies associated with in-situ paddy straw management

The technical solution pertaining to straw management problems commenced with the development of simple chopper harvester (Pilcher,1983). He concluded that apart from the problems with the epicyclic and pump drive gearbox, the mini rotor was reasonably reliable and certain shortcomings were determined. The output of the machine was found to be disappointingly low, but even when conditions are good, it is doubtful whether more than 25 tonnes cane per hour will be harvested or not. The wide range of field conditions in which the machine has operated and which are not ideal for chopper harvester is typical of South Africa. Advancement in the chopping system of machine was conducted by Tajiuldin and Kltruiumidhi (1994). He developed a sort of attachment to the prime-mower of the self-propelled reaper i.e., flail-mower. The flail-mower was evaluated for harvesting of forage; however, the machine was found suitable for chopping and fine tuning of bushy plants especially parthenium. The study concluded that the effective field capacity of the mower was about 0.20 ha/h whereas, the operational cost of mower was ascertained as 140 Rs/ha.

Significant and inaugural reformation in paddy straw management through technical approach was doneby Garg (2004), who developed paddy straw chopper-cum-spreader operated by 45 hp tractor and has 228 cm width of cut for paddy straw management. The chopper was equipped with rotary shaft mounted with flail blades to harvest the straw (at 900 rpm) and chopping unit which incorporates knives with speed of 1500 rpm. The machine harvests the paddy stubbles left following combining, chops the loose straw and standing stubbles at about 7-10 cm and subsequently spreads the chopped straw on the ground in a single operation. The chopped stubbles are then easily buried in the soil by the use of single operation of rotavator or disc harrow and decayed after irrigation. Consequently, wheat sowing operation can be performed typically by the use of strip till drill, no-till drill or traditional drill. The study investigated that preliminary trials on the machine yielded acceptable performance. More development commenced thereafter in paddy straw management field. Pannu (2005) developed both laboratory model and a well-designed prototype of tractor operated cross-conveyor straw thrower for concurrent sowing of wheat crop. The lab model and practical prototype consisted of pick-up reel, straw distributor and cross conveyor. The lab model was evaluated under combine harvested paddy field conditions and was stimulated in the laboratory. It was examined that the laboratory model and functional prototype performed best at same reel speed index (4.2) and conveyor speed index (4.3) in the field experiments. The belt width of designed cross conveyor was 60 cm. A new machine was developed for management of residue of different crops including paddy crop. Forage chopper was developed by Adgidzi (2007) for managing crop residues like rice straws, maize stovers, sorghum stovers, millet stovers, cowpea stems, potatoes stems and groundnut haulms. The machine can be operated using either a diesel or petrol engine of 10.5 and above. The study concluded that the average chopping efficiencies for the wet and dry materials were 86 and 92% respectively, whereas, the average chopping rate (kg/hr) for the dry and wet materials was 24 and 15.6. The average length of cut of the materials was observed as 25mm. It was indicated that the machine performed better with dry materials compared to wet materials. The machine required only one person for its smooth operation and can be used either in the rural or urban areas.

Most developments of machines involved the in-situ management of paddy residues along with direct sowing of succeeding crop i.e., wheat crop. Sharma (2014) developed a multi-toolbar no-till seed drill for surface managed loose straw conditions after combining. The machine no-till drills mounted with inverted-T type opener work satisfactory under anchored stubbles but clog frequently under loose straw conditions, to overcome this problem, he developed a multi-toolbar no-till drill with optional residue handling device. The machine was evaluated in actual un-chopped and chopped field condition both in wheat and rice crop. The developed drill was utilized for sowing of wheat and also compared with other systems of wheat establishment. Additional improvements and alterations were made by Anjum *et al.* (2015) who modified the conventional wheat straw chopper by using locally available materials making it light weight and more efficient. The performance evaluation of wheat straw chopper was carried out for three wheat varieties with two different tractor forward speeds and two levels of moisture contents. Substantial contribution in paddy straw sagacious management in field along with direct sowing of wheat crop was made by Sidhu *et al.* (2015) developed a new machine called the happy seeder. The Happy seeder (HS) cuts and manages the standing stubble and loose straw in front of the furrow openers, retaining it as surface mulch and sows wheat in a single operational pass of the field. It was examined that operational costs for sowing of wheat were about 50-60% lower with HS than with conventional sowing.

Performance Evaluation of Paddy Residue Management Machine

Thakur and Garg (2007) conducted a study on paddy straw management by chopping for sowing wheat in combine harvested field. They assessed fuel consumption and size of cut of paddy residue as performance parameters. The study focused on related parameters viz., chopper speed, forward speed and moisture content against size of cut and fuel consumption. The results showed that percent size of cut (less than 10 cm length) of paddy residue increased with the increase in the chopper speed and moisture content but decreased with increase in the forward speed. It was observed that the to get better performance of the stubble harvester-cum-chopper, it should be operated at 70% (wb) moisture content of the stubbles, with a forward speed of 2.00 km/h and at a chopper speed of 1500 rpm. The findings suggested that chopping of paddy stubble should be recommended immediately after combine harvesting because at higher moisture content chopping performance would find better.

Verma *et al.* (2009) developed an attachment for the existing combine, to evaluate performance of combine mounted straw managing system during rice crop harvesting, affected by various independent parameters. The study focused on parameters are three levels of number of rows of stationary blades (one, two and three rows), three levels of rotor speed index (30,35 and 40) and two levels of deflector angle (20ºand 30º with horizontal) were selected on the basis of uniformity of straw thrown (C.V. basis). The study concluded that uniformity of straw thrown was improved significantly when number of rows of stationary blades was increased from one to three. Similar pattern was observed when rotor speed index was increased from 30 to 40. Deflector angle had non-significant effect on uniformity of straw thrown. Optimal combination, at which there was maximum uniformity of straw thrown i.e., C.V. 15.25% was observed at combination of three rows of stationary blades, rotor speed index of 40 and deflector angle of 200. It was examined that the performance of straw managing system was at par with the performance of conventional no-till drill operated in clean field. Elfatih *et al.* (2010) evaluated the performance of the modified chopper for rice straw composting. The results showed that increasing the cutting drum linear speed from 56.6 m/s to 70.7 m/s, increased the cutting efficiency, the chopper productivity, and the power requirement by percentage of 3.7%, 2.8% and 0.9%, 57.5%, 55.9% and 41.7%, 36.8%, 28.6% and 35.9%, respectively, meanwhile decreased the energy consumption by percentage of 32.7%, 38.4 and 9% for 35 mm, 25 mm, and 9 mm concave hole diameter, respectively. They were explored that the shortest composting period 95 days was resulted by using 25 mm concave holes diameter at 66 m/s cutting drum speed, meanwhile the longest period 140 days was resulted by using the 9 mm concave holes diameter at 70.7 m/s cutting drum speed. Also, it was resulted using the 35 mm concave holes diameter at 56.6 m/s cutting drum speed.

Singh *et al.* (2011) evaluated the performance of tractor mounted straw chopper cum spreader for paddy straw management. The study considered the two levels of main parameters of moisture content of paddy straw (30 and 40%, wb), three levels of chopping speed (1300, 1450 and 1600 rpm) and three levels of forward speed (2.0, 2.5 and 3.0 km/h). The study investigated that the effect of moisture content on size of chopping was found to be non-significant and percent size of cut (up to 4 cm) of paddy straw increased with increase in chopper speed and decreased with increase in forward speed. None of the independent variables had a significant effect on uniformity of straw spread. Fuel consumption (l/h) at lower moisture content was low and it was increased with increase in chopping speed as well as with increase in forward speed. Effect of forward speed was more pronounced on fuel consumption than the effect of chopping speed. It was concluded that optimal combination was a chopping speed of 1450 rpm and a forward speed of 2.0 km/h.
Verma *et al.* (2016) evaluated the performance of tractor operated paddy straw mulcher. The results indicated that effective field capacity of the tractor operated paddy straw mulcher was 0.32 ha/h at forward speed of 2.64 km/h and average fuel consumption for the machine was 5.88 l/h. The percent chopped straw size by paddy straw mulcher up to 10 cm was 83.44%. No or very little straw accumulation was observed in operation of spatial no till drill for direct drilling of wheat after the operation of paddy straw mulcher. Ramulu (2020) developed residue management machine for effective chopping of paddy residue and simultaneously mixing it with soil of combine harvested paddy field. The developed machine was equipped with chopping unit, incorporation unit, belt and pulleys and adjustable frame. The fuel consumption, field capacity and field efficiency of the machine was determined as 12.5-14.0 l/h, 0.43-0.64 ha/h and 60.46% respectively. The incorporation and shredding efficiency of the machine was reported as 95.31% and 61.92% respectively at a forward speed of 2.1 km/h and at rotary speed of 1100 rpm. However, the machine required large hp tractor for its smooth operation owing to its heavy weight.

Current technical solution followed by farmers for in-situ paddy straw management

Farmers in north-western region of India follows several technical options to manage and circumvent paddy straw related problems. The related technologies are an effective alternative to open field paddy straw incineration.

(1) Super Straw Management System (SMS):

The super straw management system is an attachment to the combine harvester which is incorporated at the rear of the combine harvester adjacent to the straw walker for the purpose of fine chopping, slicing and spreading the chopped paddy straw on the soil surface. The attachment was developed by Punjab Agricultural University (PAU), Ludhiana with the ultimate thrust of in-situ paddy

Fig. 1: A view of a combine fitted with super SMS during its field testing

straw management. It consists of rotating rotor having 1500-1800 rpm equipped with double flail blades of thickness 3-4mm for fine chopping of standing stubble and throws against the stationary comb blades fixed in the comb. The rotational motion of the two spinners produces sufficient air current for the uniform distribution of the loose straw from the straw walker and chaffer sieves.

Hence, the best viable and feasible solution for the in-situ management of paddy straw is using super SMS attachment in every combine to efficaciously manage bulk paddy residue accumulation.

(2) Zero till drill: The machine offers sowing of a wheat crop precisely with limited soil disturbance into a rice residue field. It is primarily used to drill wheat seeds directly into standing rice stubbles. Zero-till-drill reduces time and energy. This technology was first developed by GBPUAT, Pantnagar. This machine can also be operated post the collection of straw using rake and baler machine. The field capacity varies from 0.34 to 0.4 ha/h. This machine can be easily operated using 35 hp or above tractor for its smooth operation.

(3) Spatial till drill: This machine allows sowing of wheat crop in rice harvested field after operation of straw chopper. Spatial drill is similar to zero till drill, the only difference is the arrangement of furrow openers in three lines. This arrangement allows passing the loose straw between the two adjacent furrow openers thus it avoids choking of them. The field capacity of this machine is about 0.35 ha/h and can be operated by 40 hp tractor or above.

(4) Happy seeder: Happy seeder is a tractor operated implement which is employed for directly sowing of wheat seeds in the soil surface covered with the mulch retention of left-over previous crops without the application of tillage. It consists of a rotating rotor incorporated with flail blades that chops the standing straw and allows it to fall on the soil surface followed by drilling and placing the seeds at the desired place and at the required depth on the surface mulch. This implement is based on the conservation agriculture deployed for sowing of wheat on the left over chopped post- harvest paddy residues (Figure 3a). It is a tractor PTO driven machine which can be operated by 45 HP tractor and have field capacity of 0.30-0.35ha/h. The paddy residues are retained on the soil surface for their effective utilization and thereby enhancing the soil physical properties by imparting the requisite nutrients including N, P and K.The utilization of happy seeder also reduces the weed growth by 50% as compared to the traditionally sowing machines. Various investigations have shown that about 15-20% water is saved due to avoidance of first irrigation and mulching. People in Punjab, India mostly rely on the happy seeder for direct sowing of the wheat crop just after post-harvesting of paddy crop.

Numerous studies have reported that sowing of wheat seeds by happy seeder on the paddy retention mulch created by the super SMS has given the commendable results in enhancement of soil moisture, yield and productivity. The Government of Punjab has recommended the manufacturers to attach the super SMS attachment in every combine manufactured after 2018 onwards (Figure 2).

(5) Paddy Straw cum Chopper

It is an implement involving in-situ management of paddy residue by chopping and slicing the paddy straw left in the field after combine harvesting into small pieces and uniformly spreading the chopped

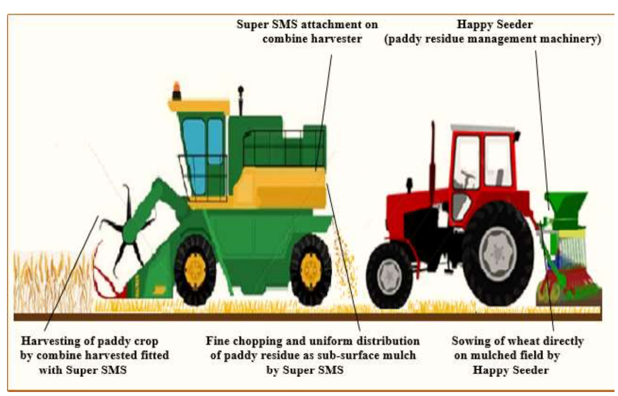

Fig. 2:Sowing of wheat seeds by happy seeder directly after combine harvesting (with SMS technology) of paddy crop

Fig. 3: (a) Happy seeder (b) Mulcher

straw in the field. This chopped straw can be incorporated into the soil afterwards and drilling of the wheat can be successively accomplished. Hence, the farmers do not need to burn the post-harvest paddy residues left in the field. This imparts much needed organic content to soil thereby improving soil health. The field capacity of the machine is 0.3 ha/h.

(6) Mulcher

Mulcher is similar to chopper and is usually used for shredding the crop residues into fine, smaller pieces and thereafter spreading it on the field. This mulched straw serve as bio mulch and decomposes gradually, improving overall organic structure of soil. After mulching of the residues, (Figure 3 (b)) the wet mixing of the mulched straw with the soil is accomplished with the rotavator thereby, allowing the surface incorporation of mulch with the soil. The effective field capacity of the tractor operated paddy straw mulcher is about 0.30-0.35 ha/h. The mulcher can chop the residue by 10 cm size with an average fuel consumption rate of 5.88 l/h.

(7) Super seeder

Super seeder is one of the effective paddy residue management implement through which the standing paddy straw, stubbles and loose straw in the field can be incorporated. It consists of rotavator attachment which helps in incorporating the paddy residue in the field but is operated by slightly high horsepower tractor. Thus, the paddy straw is incorporated unlike in happy seeder where the straw is retained in the field. Super seeder offers sowing of wheat seeds, fertilizing the field and incorporating mulch in the field after the harvesting operation of the previous crop (rice). Most of the farmers in Punjab emphasize super seeder over happy seeder as it affects economy, feasibility, yield and maintains soil fertility thereby enhancing yield of the crop. The field capacity of super seeder machine lies in the range 0.3-0.4 $ha.h^{-1}$ and can be operated by 45-50 hptractor (Figure 4).

(8) Smart seeder: The machine combines the

Fig. 4:A view of field testing of Super seeder

concept of simultaneous retention and incorporation of paddy straw with concurrent sowing of wheat post paddy harvesting by combine. The machine incorporates some part of straw into soil by executing strip tillage inrows and remaining part of straw is spread on the surface as residue mulch. The sowing of wheat is performed in rows where striptillage operation has been carried out. The straw left on the surface as mulch helps in the minimization of weed compared to other methods. The machine was developed by PAU (Punjab Agricultural University), Ludhiana. The field capacity of smart seeder varies from 0.38 to 0.4 ha/h and it can be efficiently operated with 45 hp or above tractor.

CONCLUSION

The chopping and in-situ management of paddy stubbles is suggested without delay after combine harvesting to affect timeliness. According to literature investigated by researchers, numerous machines were developed for paddy straw management in India and other countries involving high horsepower tractors for their smooth operation. Very less machines are developed requiring less than 40 hp tractor. Hence, the main thrust and top priority should be given to the development of a machine which can efficiently work on less hp tractors. On this basis of the current review, it is investigated that there is a need of technology that can match the power requirements with the available population of tractor of less than 40hp as majority of marginal, small and medium farmers possess less hp tractors. Therefore, technical aspect in dealing straw management issues should focus on economically viable and sustainably feasible technology for meeting the need of the hour of every farmer that can ponder the paddy straw management issues pragmatically.

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Received: August 29, 2023
Accepted: September 11, 2023