OPEN ACCESS

Int. J. Agr. Ext. 12 (02) 2024. 203-211

DOI: 10.33687/ijae.012.002.5199

Check for updates

Available Online at EScience Press

International Journal of Agricultural Extension

ISSN: 2311-6110 (Online), 2311-8547 (Print)

https://esciencepress.net/journals/IJAE

EVALUATION OF DIFFERENT RICE STRAW MANAGEMENT PRACTICES FOR WHEAT SOWING IN RICE-WHEAT ZONE OF SHEIKHUPURA, PUNJAB, PAKISTAN

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ARTICLE INFO

Article History

Received: January 21,2024

Revised: June 28,2024

Accepted: July 28,2024

Keywords

Rice Straw Management

Zero Tillage

Happy Seeder

Rotavator

Mould Board Plough,

Benefit Cost Ratio

Yield

ABSTRACT

Wheat Sowing is a problematic process in rice-wheat cropping systems because of heavy rice-straw load in combined harvested fields so the objective of the study was to evaluate different rice straw management practices for wheat sowing and ultimately impact on wheat crop yield. This study was conducted at Adaptive Research Farm Sheikhupura, for 2021-22 and 2022-23. This study includes four treatments Treatment 1: Burning of rice straw and stubbles followed by seed bed preparation by rotavator and broadcasting seed, Treatment 2: Use of rice straw chopper + MB Plough (1) + Rotavator (2) + Planking followed by drilling, Treatment 3: Use of rice straw chopper + Disc Harrow (1) + Rotavator (2) + Planking followed by drilling and Treatment 4: Use of zero tillage happy seeder. Complete Randomized Design (CRD) was used for statistical analysis. Yield data was collected from three replications in each treatment. Among all these methods, Treatment 2 performed higher in terms of yield data, 4443.3 kg/ha & 4538.7 kg/ha for both years 2021-22 and 2022-23, respectively associated with a higher cost of operation. Zero Tillage Happy Seeder performed at par with Treatment 2 in terms of yield data 4346.7 kg/ha & 4512.7 kg/ha for both the years 2021-22 and 2022-23, respectively, with minimum cost involved and single-step wheat sowing process and excellent rice straw management option for wheat sowing in rice-wheat cropping system. Based on these results, Zero tillage happy seeder technology may be replicated as demonstration sites on different farmer fields, so it should be adopted rapidly all over Rice-Wheat Cropping System for the betterment of farmers' economic condition, optimum wheat crop yield and for copping the rice straw burning issues and their impact on the environment.

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INTRODUCTION

Wheat is an important cereal crop grown on large scale worldwide (FAOSTAT, 2022). In Pakistan, wheat was sown on an area of 9043 thousand hectares in 2022-23 as compared to 8977 thousand hectares in 2021-22, which showed an increase of 0.7%. The contribution of wheat crop in terms of value addition to agriculture is 8.2 % and value addition to GDP is 1.9 %. Total wheat production in 2022-23 has been observed as 27.634 million tons as compared to 26.208 million tons in 2021-22, which shows an increase of 5.4 % (Government of Pakistan, 2023). Punjab province contributed 76.7% to the total wheat production of the country in 2022-23(Punjab Agriculture Statistics, 2023).

The rice-wheat system is practiced in the nearly 13.5 million hectares in the Indo-Gangetic Plains of South Asia and plays a significant role in sustainable food production for a huge population (Gupta et al., 2022). In Punjab Pakistan, wheat is cultivated in four different zones, Cotton-Wheat Zone, Rice-Wheat Zone, Mixed Wheat Zone and Pulses-Wheat Zone. In rice-wheat cropping system, wheat sowing is a complicated process. In the rice-wheat belt of Punjab, rice harvesting primarily relies on combined harvesters. However, some farmers employ sickles and reapers followed by manual threshing. In Pakistan, farmers encounter challenges with threshing rice using mechanical threshers. The tall Basmati rice varieties often wrap around the thresher drum, complicating the separation of grains from the panicle. The Government of Pakistan has permitted duty-free imports of combine harvesters since 1995-98 to address these issues. Most of these harvesters imported from other countries are models dating back to the 1990s (Kalwar 2023). Combine harvesters like the New Holland 8070 scatter loose rice straw unevenly, whereas Kubota rice harvesters release rice straw uniformly, commonly utilized as animal feed. Rafique etal. (2019) reported 59 % rice harvesting by simple combine harvesters, 28% using kabuta rice harvesters, and 13 % manual harvesting in Gujranwala district of Punjab. Kabuta harvested rice straw is used as an animal field whereas farmers burn rice straw exit by simple combine harvesters for sowing the next crop. Certain combined harvester models feature SMS (Straw Management Systems). These SMS systems chop the rice straw finely and disperse it across the field, while others crush the straw finely, gather it intact, and release it in bundled form. Combine harvesters with these SMS have a high cost of operation as compared to simple combine harvesters, which an ordinary farmer cannot afford, and they have to use simple re-conditioned combine harvesters, which disperse a considerable amount of loose rice straw not manageable by ordinary tillage implements. Combine harvesters leave the field with stubble firmly attached to the ground and loose straw piled in rows above the harvested crop. This situation prevents conservation agriculture equipment from effectively functioning under these field conditions and managing straw where it lies (Singh et al., 2020). It is very difficult to manage the combined harvested rice straw for wheat sowing. In cropping systems centered around rice cultivation, handling paddy straw (6-8 tones per hectare) in fields presents a significant challenge (Chauhan et al., 2012). Farmers typically resort to the prohibited practice of burning paddy straw in their fields following combine harvesting. In Thailand, farmers also burn the huge amount of rice straw left by harvesters in field for preparing seed bed for next crops (Tipayarom and Oanh, 2007). In Punjab, Pakistan, out of the total basmati rice area, 66% is burnt; the highest 78 % was observed in Narowal, and the lowest 15 % was observed in Lahore. 70-100 % burning of rice residues has been observed Kamoki, Pindi Bhattian, Mandi Bahaudin, Nankana Sahib, Narowal, Shakargarh, Ferozwala, Sheikhupura, Pasrur, and Sialkot Tehsils of Punjab (FAO, 2018).

In the rice-wheat system of Pakistan, farmers generally burn the rice straw and stubbles for wheat sowing, which ultimately affects the environment and causes smog and health issues. Burning of crop residues causes nitric oxide (NO), C, and carbon dioxide (CO2) emissions. Carbon monoxide (CO), Methane (CH_4), and many other gases containing nitrogen, sulfur, and other non-methane hydrocarbons (NASA 2017). Burning of rice straw affects soil temperature, organic matter content, and soil moisture in the top soil layer (Certini 2005). Mandal et al. (2004) reported many disadvantages of rice straw burning, such as loss of soil nutrients, depletion of soil organic matter content, and different biological communities. Rice straw removal and burning causes loss of valuable soil nutrients after being applied through costly fertilizer packages, ultimately affecting the cost-benefit ratio of a crop production system (Sharma et al., 2021). Burning rice straw is a common practice in different rice wheat systems because of its low cost, simple solution, the short window for the next crop, increasing rate of mechanical harvesting, and lack of consumable options for rice straw (Kaur et al., 2022). Many farmers choose to adopt burning rice straw due to the short time between rice harvesting & wheat sowing, costly manual harvesting, and labor shortages (Anuradha et al., 2021). There are multiple steps involved in wheat sowing to prepare a standard seed bed in the presence of heavy rice straw. Rice stubbles and straw are not manageable by simple ploughing and rotavator implements. Rice straw causes obstacles to different tillage operations for the seed beds of the next crops (Arunrat and Pumijumnong, 2017). All these factors ultimately affect the subsequent crop yields. After burning, farmers use disc harrows, cultivators, and rotavators to make seed beds for the following wheat crop. For wheat sowing, there is a need to avoid burning rice stubbles and straws to prevent its effect on climate and human and soil health.

For this purpose, these rice straw and stubbles need to be incorporated into the soil. An alternative to rice straw burning in India the incorporation of rice straw 15-20 days before wheat sowing has been recommended (Yadwinder-Singh et al.,2005; Singh et al., 2008). For incorporating straw into the soil and preparing the seedbed for wheat sowing, several tillage operations (such as harrowing/power tiller two to three times, or using a rotavator and planker) are necessary. This increases the cultivation expenses and postpones the wheat sowing process. Various methods are employed in rice-wheat cropping systems to integrate rice straw into the soil before sowing wheat. Some systems utilize rice straw as surface mulch or leave it on the soil. Managing rice straw requires it to be broken into smaller pieces, achieved using various chopping devices. These choppers can be integrated into harvesters for straw management or operated independently with tractors. Some advanced systems are self-propelled; following chopping, rice straw and stubble can be handled using moldboard plows and disc plows. Moldboard plows turn the chopped rice straw layer under the soil, followed by secondary tillage tools and a planker for final seedbed preparation. Several systems for rice straw management exist, such as the Happy Seeder, Super Straw Management System, Rice Straw Chopper cum Spreader, Reversible Moldboard Plow, and various no-till seeders. These technologies enable the effective incorporation of straw into the soil or its use as mulch (Chauhdhary et al.,2019). These systems are highly cost-effective, economical, and remarkably efficient, ultimately enhancing the yield of subsequent crops. Managing straw in situ, whether through incorporation or mulching, boosts soil organic matter content and enhances the soil's physical, chemical, and biological characteristics (Kaur M et al., 2022). Incorporating rice straw offers numerous benefits, including increased soil biological activity, improved soil physical conditions, and enhanced yields of subsequent crops (Mandal et al., 2004). Mulching with rice straw enhances water and nitrogen use efficiency while reducing weed density (Singh and Siddhu 2014). Paddy straw chopper cuts paddy stubbles into smaller fragments, facilitating the smooth integration of paddy straw into the soil to prepare fields effectively for wheat sowing (Singh et al., 2011). Reversible mould board plough is applied in fallow fields, which have remained unresolved for numerous years. It proves beneficial for residue handling, particularly in crops such as potatoes, sugarcane, and vegetables, where adequate field preparation is crucial for optimal establishment. Paddy straw can be shredded with a mulcher, followed by inversion using a moldboard plow, and subsequently, other initial tillage equipment can be employed to ready the seedbed (Chauhdhary et al., 2019). The Zero Tillage Happy Seeder represents an in-situ rice straw management solution, facilitating the direct sowing of wheat into previous crop residues and stubble without any soil preparation. Turbo Happy Seeder device comprises a rotor that handles paddy residues (mulching stubble) and a zero-tillage drill for wheat sowing. Flails are affixed to the straw management rotor, which cuts (strikes/shears) the standing stubble or loose straw encountered ahead of the sowing tine, cleaning each tine twice per rotor rotation to ensure precise seed placement in the soil. An essential condition for operating the Turbo Happy Seeder is uniformly spreading and drying loose straw. Additionally, it demands substantial power for operation. (Sidhu et al., 2007). Based on the analysis in above said reviews, there is a need to evaluate different rice straw management options for timely wheat sowing to avoid the burning of rice straw and to minimize its severe impact on the environment, human and soil health in rice-wheat cropping system of Sheikhupura-Punjab.

Objectives of the study

(1) To Evaluate different rice straw management options for wheat crop sowing.
(2) To study the impact of rice straw management options on wheat crop yield and benefit cost ratio of these systems

MATERIALS AND METHODS

Study Area

This study was conducted at Adaptive Research Farm Sheikhupura in Rabi 2021-22 and Rabi 2022-23 seasons. Adaptive Research Farm is located in the main city area of the district Sheikhupura of Punjab province. Total area of district Sheikhupura is 3721.574 km^2. Major crops in the Sheikhupura district are wheat, rice, sugarcane, and guava. Coordinates of Adaptive Research Farm area latitude: 31.710363^o and longitude:73.965523^o and altitude is 200 mean sea level. The average annual rainfall of the city is 635mm.

Method employed

This study consists of 4 rice straw management practices for wheat sowing laid out in Complete Randomized Design (CRD)

T_1: Farmer's practice.

T_2: Use of rice straw chopper + Mould board plough(1) + Rotavator (2) + Planking (1) followed by drilling.

T_3: Use of rice straw chopper + Disc harrow(1) +Rotavator(2) + Planking(1) followed by drilling.

T_4: Use of Happy seeder.

In the first treatment, conventional farmer's practice was tested in which rice straw was burnt. After burning, one pass of rotavator was used. Seed and fertilizer were broadcasted, and the final pass of the rotavator and planker was done. In the second treatment of the study firstly rice straw chopper was used for chopping the rice straw and stubbles. After chopping, one pass of Mold Board Plough was used to invert the chopped layer of straw beneath the soil. After that, one pass of the rotavator was done. Finally, one pass of rotavator and planker was done for final seed bed. The seed was drilled using a simple Rabi drill. In the 3rd treatment, rice straw chopper was first used for chopping the rice straw and stubbles. After that one pass of disc harrow was done to incorporate the chopped material thoroughly in soil. After disc harrowing one pass of rotavator was completed.

At last, one pass of rotavator and planker was done for the final seed bed. Drilling was done by a simple Rabi drill. In 4th treatment of the study, a zero-tillage drill known as Happy Seeder, was used in standing stubbles and straws of rice crop for wheat sowing without any land preparation. All other crop husbandry operations, i.e., fertilizer and weedicides, were adopted according to recommendations of the Punjab Agriculture Department.

Rice Straw Chopper

A rice straw chopper is a power take-off shaft-operated tractor mounted machine used to chop the rice straw and stubbles. This machine has a cylindrical shaft operated by PTO with y type flails on its periphery which apply force on rice straw and stubbles and break it into small, manageable pieces. This machine has one roller on its rearing side that presses the chopped straw layer as a mulching layer. This machine is operated 1st low gear for proper chopping process.

Happy Seeder

Happy Seeder is a zero-tillage drill that directly drills wheat seed and fertilizer in standing stubbles of rice crop. Happy seeder is a PTO-operated machine that requires a minimum 75 HP tractor. Happy seeder ensures wheat sowing without any tillage practices. This machine consists of a frame made of mild steel to which all other machine components are attached. This machine has slit furrow openers attached to tines which make soil puncture for drilling of seed and fertilizer. This machine has flail blades made of steel attached to rotor shaft. These flail blades are attached just ahead of each slit opener. Each slit opener has two sets of flail blades. These flail blades cut and throw the straw and stubbles in the way of each furrow opener and make clearing of straw and stubbles for drilling of seed and fertilizer. This seeder has a seed and fertilizer box, which is replaceable for crops other than wheat. Fluted rollers do seed and fertilizer metering. Each seed and fertilizer box has a calibration lever to adjust the desired amount of seed and fertilizer. Power is transmitted to a fluted wheel through a rotary shaft engaged with a drive wheel with a chain system. This machine also has a depth control wheel available on the rear side of the machine. This seeder is operated at 2nd low-speed gear at an RPM range of 1800 to 2000 according to a load of straw and stubbles.

Calibration of Happy Seeder

Happy seeder was calibrated for this study for the 50 kg/acre seed rate. Following steps were followed;

(1) Circumference of ground wheel : C
(2) Working width of seeder : W
(3) Distance covered by seeder for 20 revolutions of ground wheel : D = C ×20 Revolutions
(4) Area covered by machine : A = W × D
(5) Seed collection measurement for area A: S_1(kg)
(6) Seed for one acre : S_2= (S_1/A)×one acre dimensions

Rabi Drill

In 2nd and 3rd treatments, a simple Rabi drill was used for drilling the sowing after applying said treatments in the final seed bed. In Rabi, the drill seed was calibrated just like the procedure used for the Happy seeder.

Data Recording

Number of productive tiller/m^2 in each treatment was recorded using a meter square at three different locations, and these readings were averaged. Number of grains/spike or spike length was also recorded in each treatment. One thousand grain weight data for each treatment was also taken using an electronic balance. Yield data of each treatment was taken using square meters from three different locations and were averaged. Data of all yield parameters was analyzed using statistix 8.0

RESULTS AND DISCUSSION

No of Tillers/m^2

Table 1 shows no tillers/m^2 data. The maximum no of tillers was observed in treatment 4 (Use of Happy Seeder) as 375.6 and 368.6 among all other treatments for 2021-22 and 2022-23, respectively. No tillers/m2 data is significantly different among all treatments in 2021-22. Tillers of treatment 2: Use of rice straw chopper + MB Plough (1) + Rotavator (2) + Planker followed by drilling and treatment 3: Use of rice straw chopper + Disc Harrow (1) + Rotavator (2) + Planker followed by drilling were observed statistically at par for the year 2022-23. Minimum tillers were observed in treatment 1 (Farmer's Practice) as 315 and 321.3 for both years.Singh et al., 2007 observed a higher no of tillers in wheat sown by happy seeder as compared to grain sown by incorporation of rice straw using reversible moldboard plough and conventional method of wheat sowing. Soomro et al. (2009) and Nasrullah et al. (2010) also observed a higher no of tillers in wheat sown by happy seeders.

Spike Length (cm)

Table 1 shows spike length data for both years. There is no significant difference in spike length among all treatments for 2021-22 and 2022-23. However, in 2021-22, maximum spike length was observed in treatment 4: Use of Happy Seeder as 11.73 cm; however, spike lengths of all treatments were observed statistically at par with each other. Nasurullah et al., (2010) observed higher spike length in wheat sown by zero tillage happy seeder than wheat sown by conventional method. Minimum spike length of treatment 1: Farmer's practice and treatment 3: Use of rice straw chopper + Disc Harrow (1) + Rotavator (2) + Planker followed by drilling were observed as 10.33 cm. In 2022-23, the maximum spike length was observed in treatment 1: Farmer's practice as 10.6 cm, and the minimum spike length was observed for treatment 2 as 10.2 cm.

No of grains/ spike

Table 1 shows no of grains/spike data. In year 2021-22, maximum no of grains were observed in treatment 2: Use of rice straw chopper + MB Plough (1) + Rotavator (2) + Planking followed by drilling as 51. Minimum number of grains in the year 2021-22 was observed in treatment 1: Farmer's practice as 43. No of grains/spike in wheat sown by happy seeder were found statistically at par with treatment 2. In year 2022-23, the maximum no of grains observed in Treatment 2 was 49, and the Minimum no of grains observed in Treatment 3: Use of Rice Straw Chopper + Disc Harrow (1) + Rotavator (2) + planking followed by drilling as 42.6.

1000 grain weight (Gram)

In 2021-22, maximum 1000 grain weight was observed in treatment 2 as 44.20 gram and minimum 1000 grain weight in treatment 1 as 40.26. Some trend was observed in year 2022-23 as 45.36 for treatment 2 and 41.33 for treatment 1. 1000 grain weight of treatment 4: Use of happy seeder was observed statistically equal to treatment 2 as43.50 and 44.06 for the years 2021-22 and 2022-23 respectively.

Yield (kg/ ha)

Minimum yield data was observed for treatment 1: Farmer's Practice as 3846.7 kg/ha and 4036.0 kg/ha for 2021-22 and 2022-23 respectively.Maximum yield data was observed for treatment 2: Use of rice straw chopper + MB Plough (1) + Rotavator (2) + Planking followed by drilling as 4443.3 kg/ha and 4538.7 kg/ha for the years 2021-22 and 2022-23 respectively. Yield data for treatment 4: Use of Happy seeder was observed statistically at par with treatment 2 as 4346.7 kg/ha and 4512.7 kg/ha for 2021-22 and 2022-23, respectively. Treatment 3: Use of rice straw chopper+ Disc Harrow (1) + Rotavator (2) + Planking followed by drilling performed at 3rd number as 4260 kg/ha and 4232.7 kg/ha for the years 2021-22 and 2022-23 after treatment 2 and treatment 4. Yield data shows the higher performance of treatment 2 in which rice straw chopper was first used to chop the straw into small pieces, then MB plough was used to invert this mulching layer below the soil. After that, a rotavator and planker were used to prepare the proper seed bed, followed by drilling. There are multiple steps to reach the sowing process of wheat; on the other side, treatment 4: Use of only Happy Seeder in the presence of straw and stubbles performed at par in yield data with treatment 2 in a single step for sowing of wheat crop. There is no significant difference in yield data between treatment 2 and treatment 4. Singh et al. (2020) observed a 3.3 percent higher yield of zero tillage happy seeder compared to the reversible moldboard plough incorporation method. Singh et al., (2018) observed a higher wheat grain yield of zero tillage happy seeder than the conventional wheat sowing method. Sidhu et al. (2007) and Naresh et al. (2011) observed an average 9-15 % higher yield of zero tillage happy seeder than conventional wheat sowing method. Zero tillage happy seeder includes surface retention of rice straw, which maintains temperature and moisture of soil in a better way which may improve wheat crop yield. Treatment 3: Use of rice straw chopper + Disc Harrow (1) + Rotavator (2) + Planking followed by drilling produced a yield as 4260 kg/ha and 4232.7 kg/ha, respectively, for 2021-22 and 2022-23. These treatments also include multiple steps associated with the sowing of wheat as compared to Happy Seeder.

Benefit Cost Ratio

Table 2 shows the benefit-cost ratio data of all treatments for 2021-22 and 2022-23. The minimum benefit cost ratio was observed for treatment 1 as 1.76:1 and 1.23:1 for 2021-22 and 2022-23, respectively. In treatment 1, all rice straw and stubbles were burned then simple rotavator and planker was used for seed bed preparation along with broadcasting seed. Minimum yield data 3846.7 kg/ha and 4036.0 kg/ha for 2021-22 and 2022-23, respectively. was observed in this method, which ultimately depicts the low benefit-cost ratio as compared to other methods. Treatment 2: Use of rice straw chopper + MB Plough (1) + Rotavator (2) + Planking (1) followed by drilling showed the benefit-cost ratio as 1.85 :1 and 1.23: 1 for the years 2021-22 and 2022-23 with yield data 4443.3 kg/ha and 4538.7 kg/ha for the respective years. This treatment includes multiple steps involved in wheat sowing and the high cost associated with these operations.Similarly, higher time is consumed in these operations.

On the other hand maximum benefit-cost ratio was observed in treatment 4: Use of happy seeder in the presence of rice straw and stubbles as 2.02: 1 and 1.52: 1 for the years 2021-22 and 2022-23 and yield data 4346.7 kg/ha and 4512.7 kg/ha for the respective years respectively. This treatment includes a single step drilling process of wheat in the presence of rice straw and stubbles and low cost associated with this single operation compared to Treatments 2. Treatment 3: Use of rice straw chopper + Disc Harrow (1) + Rotavator (2) + Planking followed by drilling also include multiple steps for sowing process and higher costs associated with these operations as compared to Treatment 4. Benefit-cost ratios 1.76:1 and 1.10:1 was observed in Treatment 3 with yield data 4260 kg/ha and 4232.7 kg/ha for the years 2021-22 and 2022-23, respectively. Farid et al. (2017) observed a higher benefit-cost ratio for zero tillage happy seeder as compared to the conventional sowing method. Singh et al., 2020 observed a high benefit cost ratio of zero tillage happy seeder compared to wheat sowing by rice straw incorporation using reversible moldboard plough and wheat sowing by the conventional method of burning straw and stubbles. Mehmood et al., 2021 observed a high benefit cost ratio of zero tillage happy seeder sowing 2.3: 1 compared to wheat sowing using disc harrow along with burning and without burning rice straw. These all results show Zero Tillage Happy Seeder is a promising technology for wheat sowing in rice-wheat zones associated with lower cost, single operation, and timely sowing. Happy seeder technically requires only uniform spreading of rice straw in the field and appropriate moisture content and technical expertise of machine operator.

CONCLUSION

Based on all results and discussion, it is concluded that zero tillage happy seeder is an excellent technology for wheat sowing in the presence of rice straw and stubbles with a maximum benefit-cost ratio. The use of happy seeders requires uniform distribution of rice straw manually or by some mechanical spreader. This technology is recommended for the farmers of rice-wheat cropping systems for timely sowing of wheat crops in heavy rice residues with minimum cost to cope with the issues of rice straw, its burning, and smog issues, which ultimately will improve the quality of the environment, human and soil health. Furthermore, in prevailing situations of increasing fuel prices and climate change, this technology can play a crucial role in sustainable wheat production in rice-wheat cropping system. All stakeholders should make efforts to increase the outreach activity at farmer' s fields regarding this technology through demonstrations at farmers' field sites and conducting farmer days about the use of happy seeder machines.

Table 1. No of Tillers/m^2, Spike Length, No of Grains/Spike, 1000 grain weight (gram) and Yield (kg/ha).

Treatments	No of Tillers/m^2		Spike Length (cm)		No of grains/spike		1000 grain weight (gram)		Yield (kg/ha)	
	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23	2021-22	2022-23
(1) Farmer Practice	315.0d	321.3c	10.3b	10.6a	43.0b	43.3b	40.2c	41.3c	3846.7b	4036.0c
(2) Use of Rice Straw Chopper + MB Plough (1) + Rotavator (2) + Planker followed by drilling	351.3b	341.6b	11.2a	10.2a	51.0a	49.0a	44.2a	45.3a	4443.3a	4538.7a
(3) Use of Rice Straw Chopper + Disc Harrow (1) + Rotavator (2) + Planker followed by drilling	330.6c	334.6b	10.3b	10.3a	49.0ab	42.6b	42.0b	43.7b	4260.0a	4232.7b
(4) Use of Happy Seeder	375.6a	368.6a	11.7a	10.5a	46.6ab	45.0ab	43.5a	44.0ab	4346.7a	4512.7a
LSD @ 5%	15.23	8.39	0.85	0.78	6.84	5.58	0.80	1.4	191.81	11.79

Table 2. Benefit Cost Ratio for the years 2021-22 and 2022-23.

Treatments	Benefit Cost Ratio 2021-22	Benefit Cost Ratio 2022-23
(1) Farmer Practice	1.76: 1	1.23: 1
(2) Use of Rice Straw Chopper + MB Plough (1) + Rotavator (2) + Planker followed by drilling	1.85: 1	1.23: 1
(3) Use of Rice Straw Chopper + Disc Harrow (1) + Rotavator (2) + Planker followed by drilling	1.76: 1	1.10: 1
(4) Use of Happy Seeder	2.02: 1	1.52: 1

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