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**Sanyogita Chaudhary**
Ph.D. Scholar's, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

**Virendra P Singh**
Professor, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

**Subhas Chandra**
Chief Scientist, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

**TP Singh**
SRO, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

**SP Singh**
SRO, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

**SA Durgude**
Ph.D. Scholar's, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

**Corresponding Author**
**Sanyogita Chaudhary**
Ph.D. Scholar's, Department of Agronomy, G.B. Pant University of Agriculture and Technology, Pantnagar, U.S. Nagar, Uttarakhand, India

# Effect of wheat establishment methods and rice residue levels on yield and economics of rice and wheat under rice-wheat cropping system

**Sanyogita Chaudhary, Virendra P Singh, Subhas Chandra, TP Singh, SP Singh and SA Durgude**

## Abstract
The biggest challenge faced by Indian farmers under Rice- Wheat cropping system is the management of combine harvested rice. To manage such a huge quantity of rice residue farmers resort to burning. The burning of rice residue is not anymore, a solution for residue management as it has been banned by the Government of India due to its ill effects on the environment as well as on soil health. Rice residue contains around 0.7% N, 0.23% P, and 1.75% K and it is also an important source of micronutrients such as Zinc and is also rich in Silicon. Therefore, *in-situ* residue management is very crucial for protecting the environment as well as soil health. Two years field experiment was conducted to evaluate the effect of wheat establishment methods and rice residue levels on yield and economics of wheat and rice under rice-wheat cropping system at G. B Pant University of Agriculture and Technology, Pantnagar 2019-20 and 2020-21. The significantly higher grain and straw yield was observed under super seeder sown wheat during both the year of experimentation and the most economically feasible and environment-friendly treatment were super seeder sown wheat with loose straw removal treatment.

**Keywords:** wheat establishment method, rice residue levels, happy seeder, super seeder, Zero-till-ferti-seed drill, no residue burning, *in-situ* residue management

## Introduction
Worldwide, wheat (*Triticum aestivum* L.) is the most important extensively grown cereal crop and also the staple food of nearly 205 billion of the world population. Globally, wheat occupies around 217 million hectares are with the annual production hovering around 713 million tonnes (USDA, 2019) [10] and provides half of the all calories in the region of North Africa and West and Central Asia. In India, it covers around 30 M ha with an output of 99.70 MT with average productivity of 3371 kg/ha (MoA & FW, 2018) [7]. India shares 36% of the total foodgrains production of the world. It is the cheapest source of carbohydrates (60-80% mainly as starch), proteins (8-15%, containing adequate amounts of all essential amino acids except lysine, tryptophan, and methionine), fats (1.5-2.0%), minerals (1.5-2.0%), vitamins (such as B complex and E) and 2.2% crude fibers. The Rice-wheat cropping system (RWCS) in the Indo-Gangetic plain falling in South Asia covers 12.3 M ha in India (Brar *et al*., 2019) [2]. This system is of immense importance for ensuring food security in India and for sustaining the livelihoods of billions of rural and poor people.

With the advancement of farming practices, the mechanization in agriculture is increasing. In present-day agriculture, not only the sowing but harvesting is also done by the machines owing to shortage of labour, high cost of manual harvesting, and timely completion of the harvesting operation. The highly mechanized harvesting and threshing of rice using combine harvesters is a common practice in North-West India. In the process, residues left behind the combine harvester remain in two forms i.e., standing stubbles and loose residue in a narrow strip with a thickness of 15-20 cm. Unlike manual harvesting, combine leaves almost the entire residue in the field. Between rice harvest and wheat sowing, there is only a gap of 15-20 days and effective management of the entire residue in this short span for timely planting of the wheat crop is a very-2 difficult task. Therefore, the farmers commonly opt for burning rice residue in the combine-harvested fields due to a lack of access to user-friendly, cost- and time-effective options.

It has been estimated that in NW states of India about 23 MT of rice residues are burnt annually. Extensive residue burning results in the production of a copious amount of harmful gases. An acre of paddy field produces around 2.5 tonnes of stubble which, on burning, releases 7.5 kg of particulate matter, 150 kg of carbon monoxide, 3,650 kg of carbon dioxide, 498 kg of ash, and 5 kg of sulphur dioxide (Mooventhan *et al*., 2018) [8] and the black carbon emitted during residue burning warms the lower atmosphere, which is the second most important contributor to global warming after $CO_2$ (NAAS, 2017). The burning of rice residue degrades the soil health due to the loss of soil organic matter and plant nutrients (Brar *et al*., 2019 and Bisen *et al*., 2017) [2, 1]. About 90% of N and S and 15-20% of P and K contained in rice residue are lost during burning. Thus, the need for providing a cost-effective and farmer-friendly option for the management of rice residue is a major challenge as well as an opportunity for the sustainability of the intensive RWCS in North-West India. Therefore, management of residue is pertinent, to resolve various problems being encountered with the burning

On-farm management of rice residue i.e., surface retention or incorporation (*in-situ*) and composting (*ex-situ*) are the promising options to address the issue. *Ex-situ* rice residue management is not adopted at a large scale by the farmers as it is energy and cost-intensive. At the field level, *in-situ* management of the rice residue is probably the best option. Over the years, different *in-situ* rice residue management options have been notified and many machines have been developed to accomplish the task. Implements/machines like Combine harvester with the straw management system, Residue chopper, Rake, Baler, Residue harvester cum collector, etc. These are used for chopping the residue *in-situ* or removing the residue from the fields. For performing the sowing of wheat, various seeding devices like zero till seed drill, Happy Seeder, and Super Seeder are available, and later two have been designed to work also under residue retention conditions. Their performance depends upon the level of residue present in the field. Normal seeder does not have any residue management device except it has thin and sharp furrow openers and works well under no residue conditions. Happy Seeder is a type of seeding device which cuts rice straw into small pieces, sows wheat into the soil, and deposits the straw over the sown area as mulch (Singh *et al*., 2007). Thus provide the option of surface-retention rice residue rather than incorporation and burning. Super seeder is a multi-task seeding device consisting of a Rotavator, coulter, and seed drill. It incorporates the residue into the soil leading to clean cultivation. Coulter presses the soil and prevents the residue trapping with the furrow openers. As a result, the wheat is sown smoothly somewhat matching with conventional tillage. Therefore, it was thought pertinent to study the performance of different tillage options/ seeding devices under the limited and total load of rice residues. Keeping the above issues, concerns, and possibilities in mind a field investigation will be conducted to compare the performance of different wheat establishment options under different rice residue levels on the wheat crop to study their effect on yield and economics of rice and wheat under rice-wheat cropping system.

## Material and Method

### Experimental detail

The experiment was conducted during *2019-20* and *2020-21* at Norman E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, situated at an altitude of 243.84 m above mean sea level, 29° N latitude, and 79.3° E longitudes. The experiment was conducted in Split Plot Design with three wheat establishment methods viz. conventionally sown wheat (Conventional), happy seeder sown wheat (Happy seeder) and super seeder sown wheat (Super seeder) in main plot and three residue management techniques viz. complete residue removal (CRR), loose straw removal (LSR) and no residue removal (NRR) replicated thrice with the gross plot size 14× 6.6 $m^2$.

### Treatment execution

During *Kharif* season, direct-seeded rice was taken and sowing was done with a conventional zero-till-ferti-seed drill, and harvesting was done by the combine harvester. During *Rabi* season, after the harvesting of paddy loose straw was removed manually simulating as removed by Baler in complete residue removal and loose straw removal treatments. Further, in complete residue removal treatments, the remaining standing stubbles were removed manually with the help of a sickle. In no residue removal treatments, the loose residue was evenly spread over the standing stubbles and chopped into small pieces with the shredder. In the main plot after maintaining the residue levels, in conventional tillage treatments, tractor operated harrow (thrice) followed by a plank (once) followed by rotavator (once) followed by a plank (once) were used for land preparation and the sowing was done by zero-till-ferti-seed drill. Sowing in happy seeder and super seeder sown wheat was done under zero-till condition and on the same day. Pre-sowing irrigation was given in every treatment. A dose of 150 kg N, 60 kg $P_2O_5$, and 40kg $K_2O$ per hectare was applied through the urea and NPK mixture (12:32:16 % N, P, and K) in both the crop through urea, di ammonium phosphate, muriate of potash, and zinc sulphate, respectively. The varieties for the experiment were Narendra Dhan 359 (NDR-359) for rice and PBW- 502 for wheat.

### Statistical analysis

The experimental data were analyzed by using the analysis of variance technique for the split-plot design. The critical difference at 5% of significance was calculated for testing the significance of the difference between any two means wherever F-test was significant (Gomez and Gomez, 1984) [6].

## Result and Discussion

### Grain yield

Wheat establishment methods and rice residue levels did not affect the rice grain yield (t/ha) significantly during both the years of experimentation except in rice residue levels during the second year (Table 1). However, wheat grain yield (t/ha) showed a significant difference during both the years of experimentation. The numerically higher rice grain yield was recorded under Happy seeder sown wheat (6.65 t/ha) and Super seeder sown wheat (6.80 t/ha) in the first and second year, respectively. In general, the wheat grain yield was higher during the second year as compared to the first year and the mean rate of increase was 8.03 percent. The significantly highest wheat grain yield (5.55 and 5.97 t/ha, respectively) was recorded under Super seeder sown wheat during both years and was statistically at par with Conventionally sown wheat. The lowest wheat grain yield (5.03 and 5.51 t/ha, respectively) was reported under Happy seeder sown wheat during both years. The percent increase in wheat grain yield by Super seeder sown wheat over Conventionally sown wheat and Happy seeder sown wheat was 1.64, 10.33, and 2.05, 8.34 percent during the first and second year, respectively. The major contributing character for higher grain yield of wheat was the uniform crop stand under super seeder sown wheat, higher dry matter accumulation. A similar finding was reported by Gangwar *et al*., (2006) [4]. They reported that the highest grain yield was recorded under reduced tillage technique as compared to conventional and zero-till wheat and supported by Sirazunddin *et al*., (2015) [9].

Among rice residue levels, the highest rice grain yield (6.84 t/ha) was recorded under complete residue removal (CRR) which is significantly higher than no residue removal (NRR) but was statistically at par with loose straw removal (LSR) during the second year. The percent increase in rice grain yield (t/ha) by CRR over LSR and NRR was 0.29 and 6.71 percent, respectively during the second year. The highest wheat grain yield was recorded under complete residue removal (CRR) (4.98 and 5.42 t/ha, respectively) during both the years, and the lowest wheat grain yield (4.98 and 5.42 t/ha, respectively) was recorded under no residue removal (NRR). The percent increase in wheat grain yield by CRR over LSR and NRR was 5.19, 13.85, and 3.58, 11.80 percent during the first and second years, respectively. The presence of residue might lead to relatively poor contact between seed and soil which led to lower poor stand and ultimately results in poor grain yield.

## Straw yield

Wheat establishment methods and rice residue levels did not affect the rice straw yield (t/ha) significantly during both the years of experimentation except in rice residue levels during the second year. However, wheat grain yield (t/ha) showed a significant difference during both the years of experimentation (Table 1).

**Table 1:** Effect of wheat establishment methods and rice residue levels on rice and wheat yield under rice-wheat cropping system during 2019-20 and 2020-21

| Treatments | Grain yield (t/ha) | | | | Straw yield (t/ha) | | | | Harvest index | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2019-20 | | 2020-21 | | 2019-20 | | 2020-21 | | 2019-20 | | 2020-21 | |
| | Rice | Wheat | Rice | Wheat | Rice | Wheat | Rice | Wheat | Rice | Wheat | Rice | Wheat |
| **Wheat establishment methods** | | | | | | | | | | | | |
| Conventional | 6.43 | 5.46 | 6.61 | 5.85 | 9.71 | 7.18 | 9.15 | 7.59 | 39.8 | 43.2 | 43.3 | 43.5 |
| Happy seeder | 6.65 | 5.03 | 6.66 | 5.51 | 9.59 | 6.65 | 9.21 | 7.24 | 40.9 | 43.1 | 46.2 | 43.2 |
| Super seeder | 6.59 | 5.55 | 6.80 | 5.97 | 9.62 | 7.36 | 9.31 | 7.88 | 40.7 | 42.9 | 42.4 | 43.0 |
| SEm± | 0.09 | 0.10 | 0.05 | 0.09 | 0.30 | 0.11 | 0.12 | 0.11 | 0.93 | 0.81 | 0.80 | 0.37 |
| CD at 5% | NS | 0.42 | NS | 0.35 | NS | 0.46 | NS | 0.46 | NS | NS | NS | NS |
| **Rice residue levels** | | | | | | | | | | | | |
| CRR | 6.56 | 5.67 | 6.84 | 6.06 | 9.67 | 7.31 | 9.14 | 7.87 | 40.4 | 43.7 | 44.8 | 42.5 |
| LSR | 6.64 | 5.39 | 6.82 | 5.85 | 9.61 | 7.14 | 9.47 | 7.66 | 40.9 | 43.0 | 43.3 | 42.3 |
| NRR | 6.46 | 4.98 | 6.41 | 5.42 | 9.64 | 6.74 | 9.06 | 7.19 | 40.2 | 42.6 | 43.9 | 42.0 |
| SEm± | 0.10 | 0.12 | 0.08 | 0.08 | 0.12 | 0.11 | 0.13 | 0.11 | 0.55 | 0.75 | 0.80 | 0.59 |
| CD at 5% | NS | 0.37 | 0.24 | 0.26 | NS | 0.35 | NS | 0.34 | NS | NS | NS | NS |

Among wheat establishment methods, the numerically higher rice straw yield was recorded under conventionally sown wheat (9.71 t/ha) and Super seeder sown wheat (9.31 t/ha) in the first and second year, respectively. In general, the wheat straw yield was higher during the second year as compared to the first year and the mean increase was 7.22 percent. Among wheat establishment methods, the significantly highest wheat straw yield (7.36 and 7.88 t/ha, respectively) was recorded under Super seeder sown wheat during both years and was statistically at par with Conventionally sown wheat.

The lowest wheat straw yield (6.65 and 7.24 t/ha, respectively) was reported under Happy seeder sown wheat during both years. The percent increase in wheat straw yield by Super seeder sown wheat over Conventionally sown wheat and Happy seeder sown wheat was 2.50, 10.67, and 3.82, 8.83 percent during the first and second year, respectively.

Among rice residue levels, the numerically highest rice straw yield was recorded under complete residue removal (CRR) and loose straw removal (LSR) during the first and second years, respectively. the significantly highest wheat straw yield (7.31 and 7.87 t/ha, respectively) was recorded under complete residue removal (CRR) and was statistically at par with loose straw removal (LSR) during both years. The lowest wheat straw yield (6.74 and 7.19 t/ha, respectively) was recorded under no residue removal (NRR) during both years. The magnitude of increase in wheat straw yield by CRR over LSR and NRR was 2.38, 8.45, and 2.74, 9.45 percent during the first and second year, respectively.

## Harvest index

Wheat establishment methods and rice residue levels did not affect the harvest index of rice and wheat significantly during both the years of experimentation. Among wheat establishment methods, the numerically higher harvest index of rice was recorded under Happy seeder sown wheat and the numerically highest harvest index of wheat was recorded under Conventionally sown wheat during both the years. Numerically, the highest harvest index of rice was recorded under loose straw removal (LSR) and complete residue removal (CRR) during the first and second years, respectively. While in wheat, the numerically highest harvest index was recorded under complete residue removal (CRR) during both years.

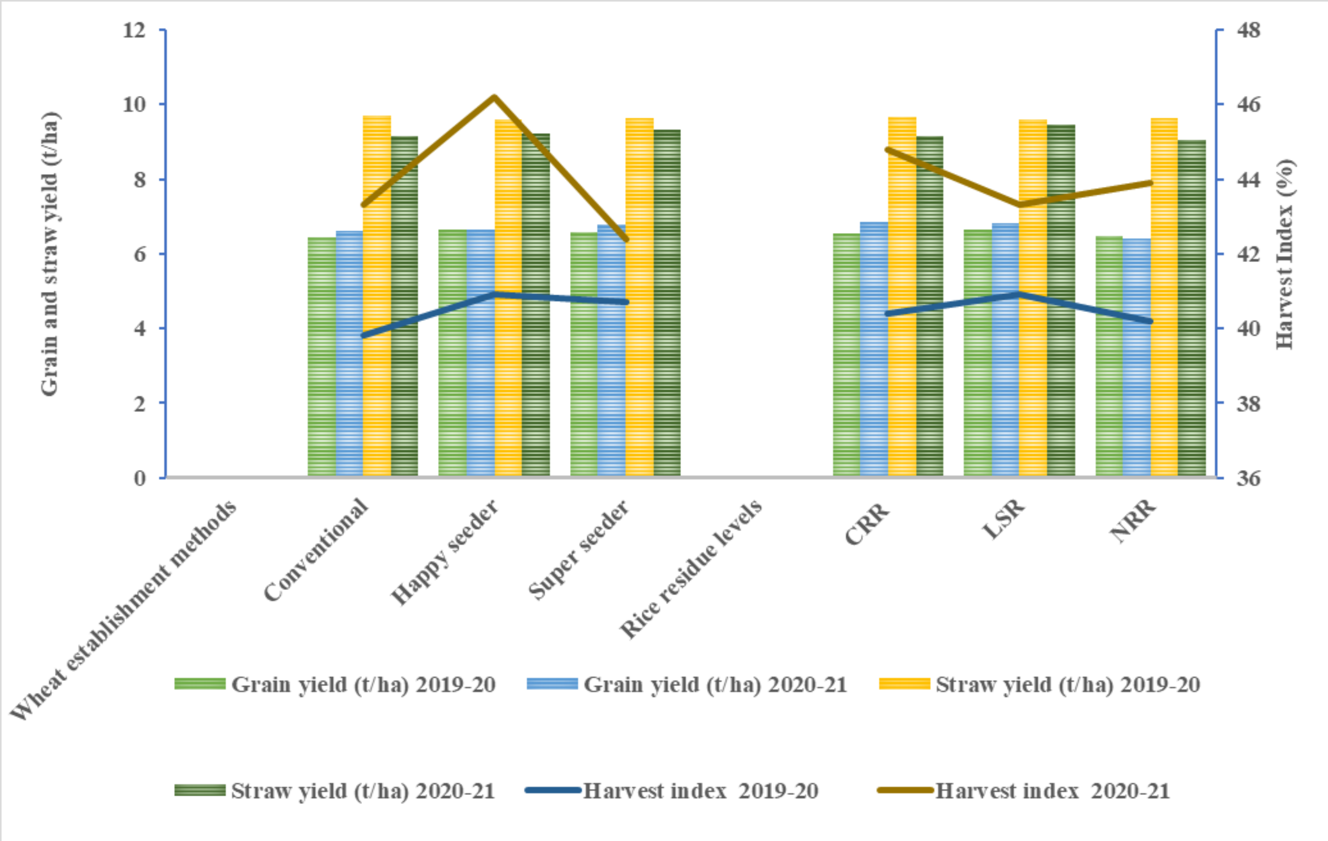


**Fig 1:** Grain yield (t/ha), Straw yield (t/ha), and harvest index of rice during 2019-20 and 2020-21

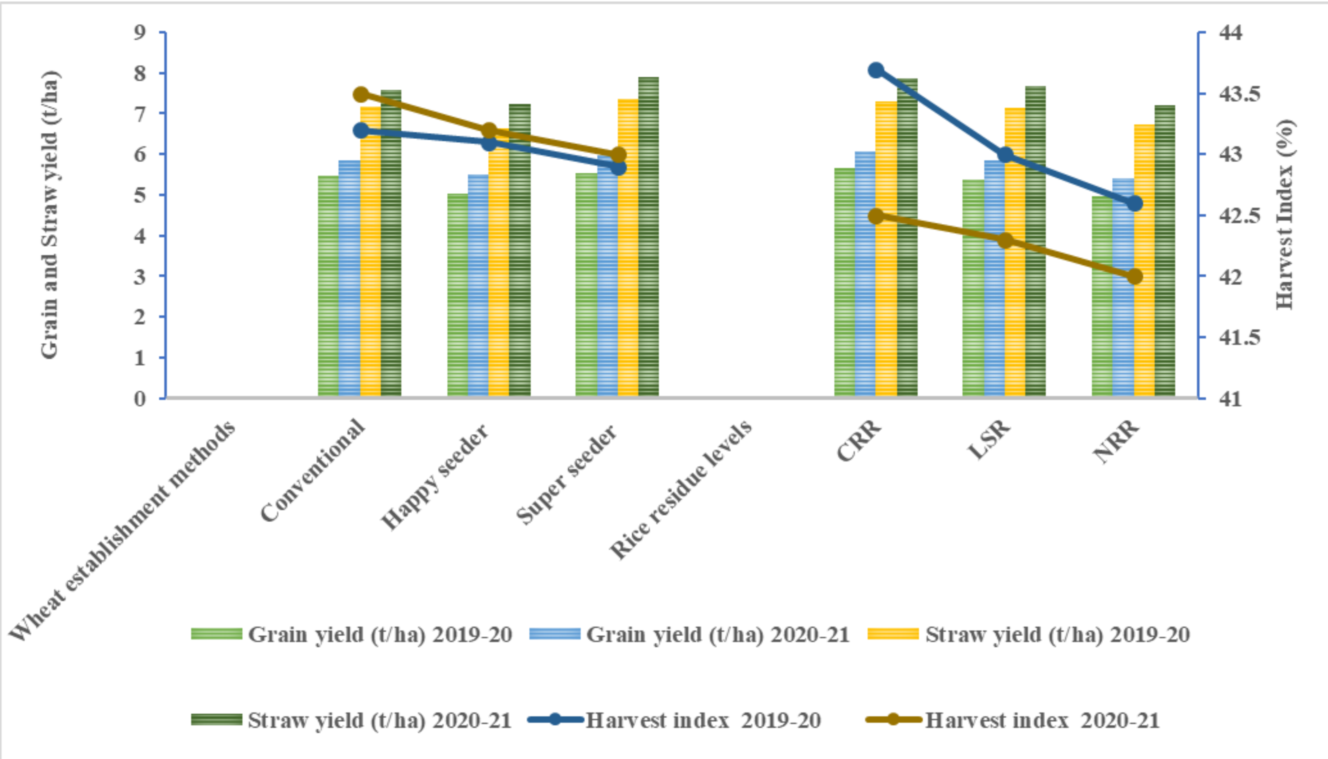


**Fig 2:** Grain yield (t/ha), Straw yield (t/ha), and harvest index of wheat during 2019-20 and 2020-21

**Economics**

The cost of cultivation of rice was equal for treatments while in the case of wheat the cost of cultivation was highest (30871 and 30575 Rs/ha) in the case of conventionally sown wheat and no residue removal treatment. The lowest cost of cultivation in wheat (29119 and 29499 Rs/ha) was recorded under super seeder sown wheat and complete residue removal (CRR) treatments. The wheat establishment method did not significantly influence the gross return, net return, and B: C ratio of rice while in the case of wheat the difference was significant. The numerically highest gross returns (125139 Rs/ha), net returns (87779 Rs/ha), and B: C ratio (2.35) of rice were recorded under super seeder sown wheat treatment. Super seeder sown wheat had significantly higher gross returns (159253 Rs/ha), net returns (130134 Rs/ha), and B: C ratio (2.41) of wheat which was statistically at par with conventionally tilled wheat except for the B: C ratio. In wheat, the percent increase in gross returns and net returns by super seeder sown wheat over happy seeder sown wheat was 10.7 and 14.4 percent, respectively. Rice residue levels significantly influenced the gross returns, net returns, and B: C ratio of rice and wheat. The significantly highest gross returns, net returns, and B: C ratio of wheat and rice was recorded under complete residue removal which was statistically at par with the loose straw removal treatment except for the B: C ratio of wheat. The present increase in the gross and net return of wheat by CRR over NRR was 13.1 and 17.6 percent, respectively. This was due to the increased number of operations during preparatory tillage i.e., use of harrow, rotavator, and plank, and residue addition was maximum in no residue removal treatment which led to higher cost of cultivation similar results were reported by Chokkar *et al*. (2007) [3]. They reported that zero-tilled wheat has a significantly lower cost of cultivation than conventionally tilled wheat supported by Gautam *et al*. (2020) [5].

**Table 2:** Effect of wheat establishment methods and rice residue levels on economics of rice and wheat under rice-wheat cropping system (2 years pooled data)

| Treatment | Economics (Rs/ha) | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Cost of cultivation | | Gross returns | | Net returns | | B:C ratio | |
| | Rice | Wheat | Rice | Wheat | Rice | Wheat | Rice | Wheat |
| **Wheat establishment methods** | | | | | | | | |
| Conventional | 37360 | 30871 | 121888 | 155504 | 84528 | 124633 | 2.26 | 4.04 |
| Happy seeder | 37360 | 30136 | 124359 | 143917 | 86997 | 113789 | 2.33 | 3.79 |
| Super seeder | 37360 | 29119 | 125139 | 159253 | 87779 | 130134 | 2.35 | 4.47 |
| SEm± | - | - | 829 | 1454 | 829 | 1453 | 0.02 | 0.04 |
| CD at 5% | - | - | NS | 5861 | NS | 5859 | NS | 0.18 |
| **Rice residue levels** | | | | | | | | |
| CRR | 37360 | 29499 | 127530 | 161566 | 90170 | 132067 | 2.41 | 4.48 |
| LSR | 37360 | 30055 | 125254 | 154236 | 87893 | 124183 | 2.35 | 4.14 |
| NRR | 37360 | 30575 | 118602 | 142872 | 81242 | 112297 | 2.17 | 3.68 |
| SEm± | - | - | 1226 | 2550 | 1226 | 2550 | 0.03 | 0.09 |
| CD at 5% | - | - | 3820 | 7944 | 3820 | 7944 | 0.1 | 0.28 |

## Conclusion

The use of a super seeder for the sowing of wheat results in significantly higher yield, gross returns, net returns, and B: C ratio of wheat. Sper seeder with loose straw removal treatment was the most promising in terms of yield, economically feasible, and is environment friendly.

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