



Research Article

Rice Residues Management Practices in Punjab: Effects on Wheat Yield and Soil Health

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Abstract | Rice-wheat cropping system is a major system in agriculture of Pakistan. Conventional practice of residues-burning has been greatly discouraged in the wake of ongoing environmental challenges. When rice crop precedes wheat sowing in same fields, the farmers are elicited to burn the rice residues for urgent land preparation which poses multiple threats to soil characteristics. This study investigates the effects of different rice-residues management practices on wheat productivity and soil health. Field trials were conducted for a period of two consecutive years (2021-22 and 2022-23) to compare the effects of eco-friendly rice-residues management practices with the unappealing conventional practice of residues burning on yield performance of wheat crop. Results reveal the highest average wheat grain yield by residues incorporation practice (4366 kg/ha) followed by zero tillage practice (4289 kg/ha) and then conventional residues-burning practice (4047 kg/ha), respectively. Similarly, greater germination count, number of productive tillers and grains per spike were observed using residues incorporation and zero tillage practices as compared to other practices. Pertaining to soil health effects, the residues incorporation and zero tillage significantly contributed to soil phosphorus (by 0.02-0.03 ppm), potassium (by 5 ppm) and organic matter (by 0.02%). Contrarily, the residues burning practice reduced the soil potassium (by 1 ppm) and organic matter (by 0.01%). The empirical findings conclude that eco-friendly practices can perform at least equally to or better than conventional practice of crop-residues burning in terms of soil health and yield of subsequent wheat crop. The study findings discourage the residues burning, and advocate the adoption of residues incorporation or zero tillage for wheat sowing followed by rice crop in order to economize agricultural production, conserve nature and minimize environmental hazards including soil degradation and smog problems.

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Introduction

The need to urgently prepare fields for sowing of wheat crop elicits the farmers to burn rice residues, and this common practice—especially in developing countries—is a matter of great concern in the wake of multiple environmental issues all over the world (Ahmed *et al.*, 2015). Conventional practice of residues-burning has been greatly discouraged in the wake of ongoing environmental challenges. Government of Pakistan has already taken number of steps and promulgated the laws to prohibit the burning of rice straw as to avoid the environmental hazards like black carbon and smog. The enforcement of these laws and improved surveillance systems are need of the time to monitor the rice-residues management practices.

Farmers' practice of burning the rice straw provokes major environmental hazards through emission of smoke and other air-pollutants which eventually cause fatal health issues including respiratory disorders (Athira *et al.*, 2019). Incomplete combustion of biomass, e.g., crop residues, generates black carbon which is a major contributor to global warming (Kante, 2009; Janssen *et al.*, 2012). Black carbon has adverse impacts on atmospheric visibility, plant photosynthesis, ecosystems, human health and glaciers melting; whereas, the reduction in emission of black carbon can help mitigate the health hazards of both the planet and human beings (Piacentini and Micheletti, 2016). Biomass burning not only increases environmental pollution but also results in significant loss of necessary soil nutrients and destruction of natural habitat of soil living microorganisms (Gupta *et al.*, 2004; Gadde *et al.*, 2009; Lohan *et al.*, 2018). Effective management of rice residues may significantly add to the mitigation of environmental hazards as well as improving soil health.

Instead of burning the biomass, incorporating the crop residues into soil can improve organic matter, organic carbon, microbial biomass and soil potential for nutrients recycling (Gangwar *et al.*, 2006; Malhi and Kutcher, 2007). This practice may lead to higher crop yield (Tripathi *et al.*, 2007; Garg, 2008). There is large consensus in literature that, in comparison to the burning practice, incorporation of crop residues improves the soil quality in the long run. Nevertheless, this needs to be confirmed under the agro-climatic conditions prevailing in the rice-wheat cropping

systems of different zones in Pakistan.

Zero tillage is another excellent alternative practice for managing the rice crop residues instead of burning. It involves sowing wheat crop without removing rice stubbles and pulverizing the soil through heavy ploughings. No-till planting implements, such as Happy Seeder machine, are available in market that allow direct sowing of wheat crop into rice-harvested fields without seedbed preparation. This practice of conservation agriculture helps preserve labor, time, energy, environment health and production cost which could lead to sustainable agriculture (Bhatt *et al.*, 2019; Zahid *et al.*, 2020). In addition, soil biochemical and physical properties (Thomas *et al.*, 2007; Page *et al.*, 2020), and organic matter are also conserved through reduced tillage (Dikgwatlhe *et al.*, 2014; Bu *et al.*, 2020).

In contrast, heavy tillage practices deteriorate soil health, ecosystem and other natural resources (Huang *et al.*, 2012; Ruan and Philip, 2013; Hassan *et al.*, 2022). Intensive tillage practices e.g., ploughing, harrowing and soil inversion can cause large-scale soil degradation in the form of surface runoff and erosion which is a global environmental challenge (Kassam *et al.*, 2009; UNDP, 2019; Adam and Abdulai, 2023). According to Zuber and Villamil (2016), conventional tillage practices greatly require fuel energy which causes GHG emissions thereby producing climate hazards.

Gupta (2012) illustrates that zero tillage (ZT) machine enables the farmers to timely sow the wheat crop after rice harvesting as it excludes the need of rice straw burning for seed bed preparation. Singh *et al.* (2010) conducted a field trial and found that ZT practice saved a considerable quantity of fuel and irrigation water with increased average yield of wheat in comparison to conventional tillage (CT) practice.

Sidhu and Beri (1989) and Gupta *et al.* (2004) find that rice straw residue incorporation has long lasting positive impacts on chemical and physical properties of soil. It enhances the nitrogen uptake (Verma and Bhagat, 1992) and increases the recycling of nutrients (Samra and Kumar, 2003; Mandal *et al.*, 2004; Kone *et al.*, 2010). In addition, Dotaniya (2013) observes the substantial increase in wheat yield through rice-residues incorporation practice. Similar results were obtained by Prasad *et al.* (1999) who found that the

incorporation of rice crop residues into soil improved the average production of wheat crop.

Literature greatly suggests that there is positive effect of zero tillage practices and incorporation of rice residues into soil on wheat yield. In addition to being eco-friendly, zero tillage technology curtails the labor requirements and cost of production as compared to conventional practices. The objectives of study are: (1) to evaluate the effect of rice-residues incorporation into soil on wheat yield, (2) to evaluate the effect of use of zero tillage implement on wheat yield, (3) to compare outcome of the above practices with conventional practice of residues-burning, and (4) to suggest key recommendations based on the study findings.

Materials and Methods

Study area

The study has been carried out in Sargodha district of Punjab. During 2022-23, wheat crop has been cultivated in Punjab over an area of 6.5 million hectares, out of which, Sargodha district shares 3.1% area. Similarly, the area under rice crop remained 5.4 million hectares with 2% share of Sargodha district (CRS, 2024). With a total area of about 1.1 million hectares, the rice-wheat cropping is the dominant system in many districts of Punjab (Bokhari *et al.*, 2017). In rice-wheat cropping system of Punjab, nearly 80% of wheat is grown after harvesting of rice crop (Ahmed *et al.*, 2015). Wheat sowing, in this system, usually gets late due to preceding rice crop especially basmati varieties (Akhtar *et al.*, 2002; Bokhari *et al.*, 2017).

Layout of field experiment

The experiment was conducted at Adaptive Research Farm, Sargodha during the two consecutive years, 2021-22 and 2022-23. The trial area is characterized by clay loam soil with pH 8.30, EC 0.29 dS/m, organic matter 0.97%, Phosphorous (P) 8.50 ppm and potassium (K) 160.00 ppm. Sargodha has a climate of extreme heat in the summers with maximum of 50°C and moderate cold in the winters with minimum temperature as low as freezing point. Weather condition during both seasons of experiment is illustrated in Figure 1 which demonstrates that the weather condition remained nearly same in both years of experiment on the average. However, first year of study was slightly warmer but less humid as compared to the second year.

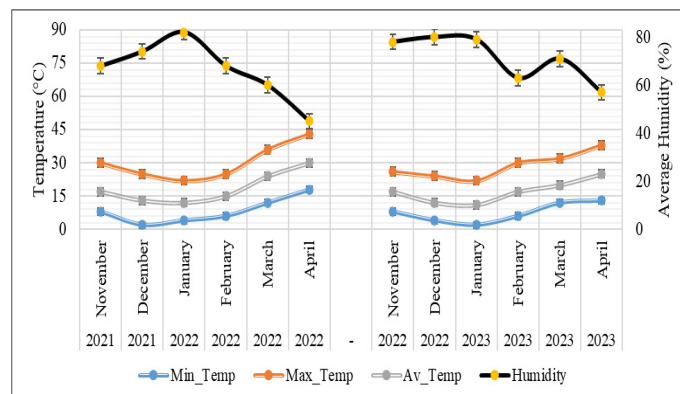


Figure 1: Weather condition in Sargodha during the field experiment for the study years.

Trial was laid out in Randomized Complete Block Design (RCBD) with four treatments, three replicates and plot size of 15 x 30 m² for each treatment. Rice crop was harvested from the field area through combined harvester. Akbar-2019 variety of wheat (procured from Ayub Agriculture Research Institute, Faisalabad) was sown in four segments of trial area: (1) in first treatment, rice crop residues were incorporated into soil using one-time disc harrow ploughing followed by wheat sowing through hand drill; (2) in second treatment, residues were burnt and then land was prepared using two-times cultivator ploughing and one-time planking followed by wheat sowing through broadcasting (farmers' practice); (3) in third treatment, residues were incorporated into soil using two-times disc harrow and one-time cultivator ploughing with planking followed by wheat sowing through hand drill; and (4) in fourth treatment, wheat was directly sown through happy seeder machine without any tillage operation. For zero tillage treatment, area was irrigated up to the field capacity level and optimum moisture was maintained for sowing of crop. Figure 2 illustrates the layout structure of different treatments in field trial.

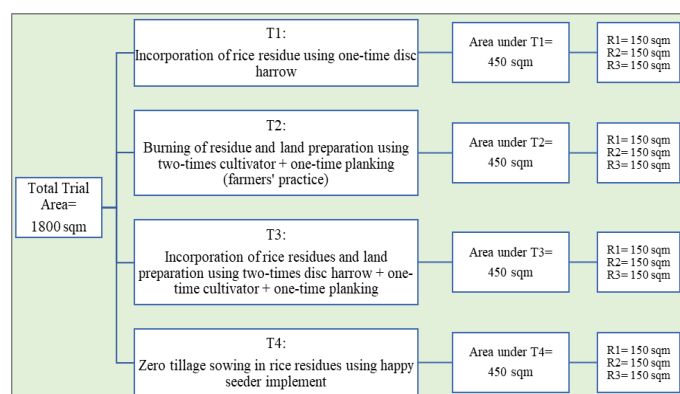


Figure 2: Layout design of trial at study site.

Seed rate was used at recommended level i.e., 123.5

kg/hectare. For the sake of uniformity, standard agronomic practices were applied to the whole field as per recommendations of Agriculture Department, Government of the Punjab (GOP, 2021). Keeping in view the average fertility level of soil, N-P-K fertilizers were applied with a proportion of 133-84-62 kg per hectare, respectively. Similarly, three irrigations were applied through canal water until maturity of crop. The crop was harvested at maturity stage on 2nd May during 2021-22 and 10th May during 2022-23. Necessary observations were recorded including germination count per square meter (sqm), number of productive tillers per sqm, number of grains per spike, thousand grains weight (gram), grain yield (kg/ha) and number of weeds per sqm.

To compare the treatment effects on soil conservation indicators e.g., accretion of organic matter and NPK, soil samples were tested in soil testing laboratory after harvesting of wheat crop for both years of experiment.

Data were analyzed using R software v4.1.2 (R Core Team, 2024). Analysis of Variance (ANOVA) was performed to check the overall treatment effects. Treatment means were compared through Tukey's Honestly Significant Difference (HSD) test at the 5% level of significance (Tukey, 1949).

Results and Discussion

This section describes overall treatment effects on different yield parameters of wheat crop as well as treatment-wise results separately for each variable. The results of statistical analysis shall enable to determine whether switching from conventional method to the zero tillage or eco-friendly conservation practices of rice crop residues management can perform satisfactorily without significant loss of wheat yield. It has been admitted fact that zero tillage practices can be economical, climate friendly, and helpful in improving and conserving the soil health. So, it is important to quantitatively measure the effects of these practices on crops yields.

Overall treatment effect

Results of average treatments effects on various yield parameters are presented in Figure 3. The experiment was conducted in the field where wheat crop was sown followed by rice crop during Rabi season 2021-22 and repeated in 2022-23 in the same field, thereby applying the treatments to same respective

plots. Empirical findings suggest that wheat crop yielded differently after using the different practices of managing the rice residues. With the exception of thousand grains weight parameter, all the parameters showed statistically significant treatment effects, ascertaining that the choice of post-harvest rice residues management practice can significantly affect the yield of next-sown wheat crop in the same field. The results for both years revealed the same trends, further supporting the significant treatment effects. In fact, different tillage practices lead to change in soil physical properties e.g., bulk density, porosity and moisture, which eventually affect the crop yield. In addition, residues burning can also affect the chemical properties including soil organic matter. These results are similar to the findings of Tahir *et al.* (2008) and Rafiq *et al.* (2017) who demonstrated that rice residues management techniques significantly affect the upcoming wheat crop yield due to different physical environments of soil.

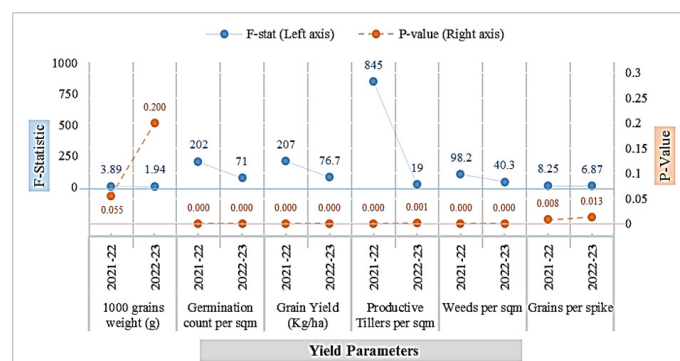


Figure 3: ANOVA results (Average treatment effects on different yield parameters).

Grouping information using Tukey method

Tukey's HSD method was used to measure individually the average effects of four treatments on yield parameters of wheat crop. Statistical significance has been shown through compact lettering wherein the same letters denote insignificant difference and unlike letters show significant difference among respective treatment effects (Table 1).

Germination count, number of productive tillers, grains per spike and grain yield were highest for T3 (residues incorporation) and T4 (happy seeder) in both years. However, thousand grains weight showed somewhat different results in varying years with the higher weight for T3 and T4 in first year and for T2 in second year of experiment. Contrarily, number of weeds per square meter was highest in T1 and smallest in T3 during both years. The results clearly depict that

Table 1: Treatment effects on yield parameters of wheat crop.

Parameter	Year 2021-22				Year 2022-23			
	T1	T2	T3	T4	T1	T2	T3	T4
Germination count per sqm	215.30 c	223.30 b	231.30 a	230.70 a	212.30 c	222.30 b	230.30 a	230.30 a
Productive tillers per sqm (No.)	241.30 c	281.7 b	301.00 a	300.30 a	256.70 b	289.70 a	304.30 a	301.30 a
No. of grains per spike	38.67 b	40.67 a	40.67 a	40.33 a	36.70 b	40.30 a	40.70 a	40.00 a
1000 grains weight (g)	34.33 b	35.00 ab	35.67 a	35.33 a	34.00 ab	34.70 a	33.70 ab	33.30 b
Grain Yield (Kg/ha)	3203.30c	4008.80 b	4366.00 a	4279.70 a	3195.80 b	4047.50 a	4166.20 a	4015.80 a
Weeds per sqm (No.)	9.30 a	4.70 b	1.30 c	4.30 b	10.30 a	4.00 b	1.70 c	5.70 b

Source: Author's own calculations. Note: Different letters denote statistical significance of difference among mean values.

Table 2: Multiple comparisons (differences between treatment effects on wheat crop).

Year	Comparison groups	Germination count per sqm	Productive tillers per sqm	Grains per spike	1000 grains weight (g)	Grain yield (Kg/ha)	Weeds per sqm
2021-22	T1-T2	***	***	***	NS	***	***
	T1-T3	***	***	***	**	***	***
	T1-T4	***	***	***	**	***	***
	T2-T3	***	***	NS	NS	***	***
	T2-T4	***	***	NS	NS	***	NS
	T3-T4	NS	NS	NS	NS	NS	***
2022-23	T1-T2	***	***	***	NS	***	***
	T1-T3	***	***	***	NS	***	***
	T1-T4	***	***	**	NS	***	***
	T2-T3	***	*	NS	NS	NS	**
	T2-T4	***	NS	NS	*	NS	*
	T3-T4	NS	NS	NS	NS	*	***

Note: Significance codes for differences: *** = 0.01 ** = 0.05 * = 0.1 'NS' = Insignificant. Source: Author's own calculations.

yield parameter was larger where number of weeds were smaller and vice versa. It implies that switching between the postharvest rice-residue management practices affects the weeds intensity which ultimately affects the yield of subsequent wheat crop. This phenomenon has been further verified through correlation analysis in next section. The results are in accordance to the findings of [Mustafa et al. \(2021\)](#) and partially to those of [Rafiq et al. \(2017\)](#). Zero tillage and residues incorporation into soil allow for better sprouting of seed and improved root growth into porous soil zone along with efficient nutrients uptake. The nutrients are absorbed into larger root-zone area with greater ease resulting in healthy wheat growth [Mustafa et al. \(2021\)](#).

Zero tillage practice is better substitute to sow wheat followed by rice crop without any hazards except weeds problem. The appropriate and timely use of weedicides may be adopted to tackle the weeds issue. Government of Pakistan has already taken number of steps and promulgated the laws to prohibit the

burning of rice residues as to avoid the environmental hazards like global warming, black carbon and smog.

The data has also been tested for multiple comparisons with the motive to evaluate the differences between varying pairs of treatments. The results are presented in [Table 2](#) which shows that many treatment pairs have significant differences between them. Except thousand grains weight, all the yield parameters revealed significant difference of average T1 from the mean of other three treatments in both years. It implies that T1 (use of one-time disc harrow for incorporation of rice crop residues) resulted in different wheat yield as compared to all other treatments.

Similarly, T2-T3 and T2-T4 also showed significant difference for most of the parameters. However, the mean effects of T3 and T4 showed no significant difference between each other in all parameters except weeds density. On the other hand, T2 (residues burning) performed at most equally or less than T3 and T4 conservation practices. This implies that wheat

yield obtained through residues incorporation practice and by the use of happy seeder was nearly equal with insignificant difference. This result advocates practicing the zero tillage technique of happy seeder for wheat sowing after harvesting of rice crop in order to save the land preparation costs and to conserve the soil health, thereby minimizing the environmental degradation caused by burning of rice residues.

Burning of rice residues pollutes the climate and destroys the flora and fauna of the soil (Lohan *et al.*, 2018; Abdurrahman *et al.*, 2020). Although there are more weeds in zero tillage sowing as compared to the farmers sowing practice, but it could be controlled by the proper use of weedicides spray. Moreover, according to the literature, zero tillage practice can also conserve more nitrogen, phosphorus, potassium (N, P, K) and organic matter in soil (Choudhary and Behera, 2014; Dutta *et al.*, 2023).

The results of multiple comparisons for yield parameter are also illustrated in Figure 4 for closer understanding. Wheat yield ranged between 3195 kg and 4366 kg per hectare during both years. To examine overall differences between each pair of treatments, the third part of Figure 4 demonstrates the results based on pooled data by omitting the time-effect (i.e., year based difference). It implies that there were four treatments with six replicates. The pairs appearing above the diagonal (45° angle) line show the negative difference between two treatments. For an instance, if T1-T2 (T1 minus T2) difference is negative, it implies greater value of the later treatment (T2) than former term (T1), and the point in graph lies above the diagonal line.

Out of all possible six pairs, two treatment pairs (T2-T4 and T3-T4) reveal insignificant differences which implies that, overall, wheat sowing through happy seeder yields at least equal to or better than T2 (residues burning) and T3 (residues incorporation practice) with statistically insignificant variation. Sowing through happy seeder resulted in significantly greater wheat yield as compared to T1 (in both years) and T2 (in first year). On the other hand, T1 (one-time disc harrow ploughing) performed the least as compared to all other treatments, apparently due to poor soil bed prepared.

Mustafa *et al.* (2021) also observed that zero tillage technique had resulted into higher wheat yield as compared to conventional or stubble burning methods. These findings can be attributed to suitable and healthy soil environment, lesser soil compaction and deeper plant roots which improve the biological and subsequently grain yield in case of zero tillage or straw incorporation into soil (Rashidi and Keshavarzpour, 2007; Šíp *et al.*, 2009).

These results favor the practice of zero tillage or happy seeder for wheat sowing after rice crop to conserve the soil health, reduce the cost of production and for cleaner agricultural production. Literature greatly suggests that, incorporation of crop residues improves the soil quality in terms of organic matter, organic carbon and microbial biomass in the long run as compared to the burning practice (Hartley and Kessel, 2005; Gangwar *et al.*, 2006; Malhi and Kutcher, 2007), and this leads to greater crop yield (Bahrani *et al.*, 2007; Tripathi *et al.*, 2007; Garg, 2008).

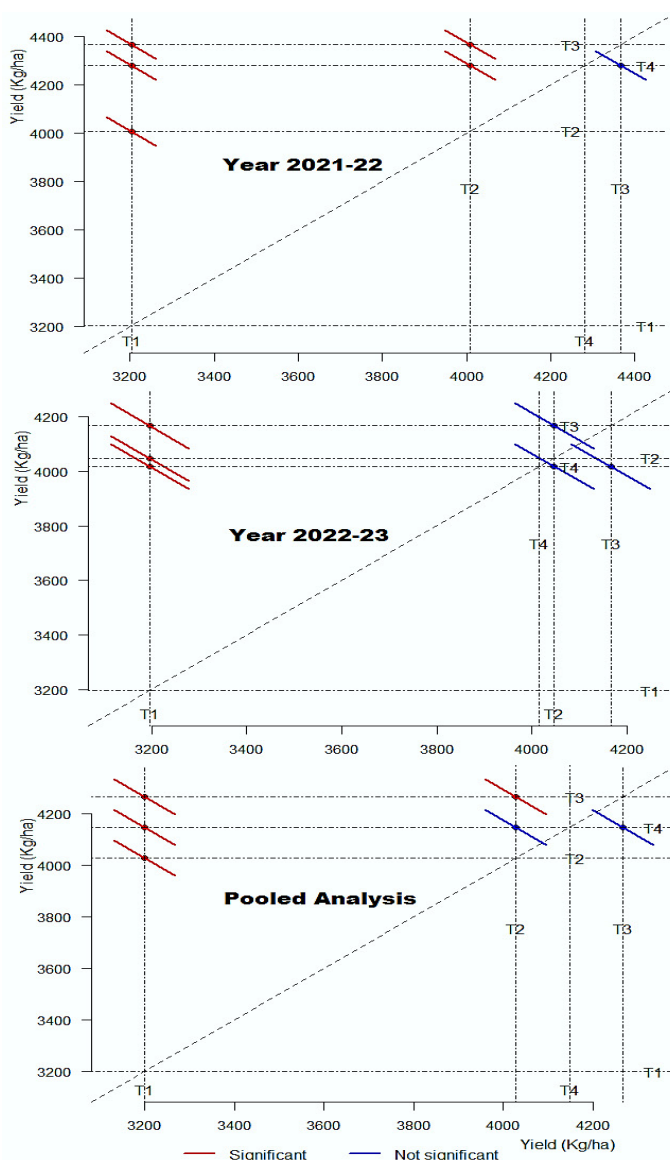


Figure 4: Wheat yield comparisons among treatments.

Zero tillage practice, a better alternative to residues incorporation and burning practice can result in good crop yield in addition to labor, time and energy saving. It improves environment health and reduces production costs significantly (Mangalassery *et al.*, 2014; Bhatt *et al.*, 2019; Bu *et al.*, 2020; Page *et al.*, 2020; Zahid *et al.*, 2020). In contrast, heavy tillage or residues burning practices cause the soil and environment degradation (Janssen *et al.*, 2012; Athira *et al.*, 2019; Hassan *et al.*, 2022; Adam and Abdulai, 2023).

Correlation analysis

Correlation analysis has been performed in order to measure the strength of linear association among variables. Figure 5 demonstrates the correlation plot of all yield parameters using aggregate data of two years. Except thousand grains weight parameter, all of the variables (germination count, productive tillers, grains per spike, yield and weeds) show a significant correlation with each other. Similarly, each variable has a positive linear correlation to the others except weeds density parameter. Correlation analysis supports previously described ANOVA findings. The higher the weeds density, the smaller would be the crop yield and vice versa. Weeds density has the strongest negative correlation (-0.92) with the grain yield. So, it may be anticipated that treatments (tillage practices) have significant effect on number of weeds per square meter, which ultimately affect wheat yield as the mediating as well as moderating agent.

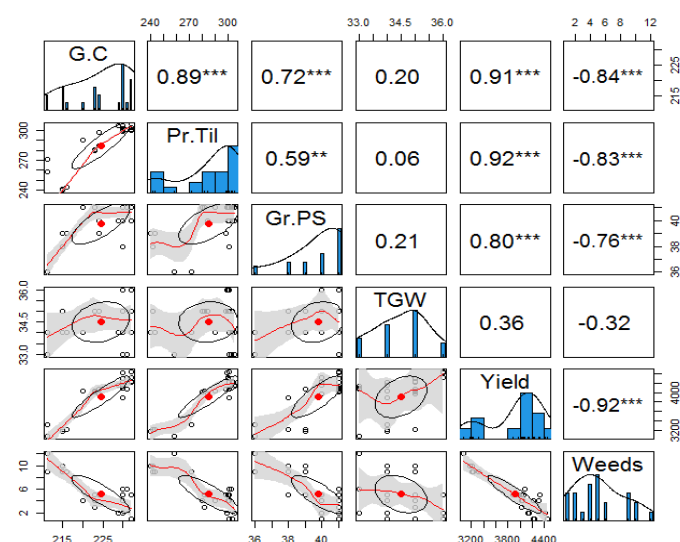


Figure 5: Correlation plot of yield parameters of wheat.

Analysis of soil nutrients (Organic Matter and NPK)

Soil samples were collected from depth of 0-6 inches (topsoil) and 6-12 inches (subsoil), and

tested in district soil testing laboratory. Test results demonstrate that overall soil health was improved through rice-residues incorporation and zero tillage practices (Figure 6). After harvesting of wheat crop of second year, soil organic matter was found highest (0.995%) for T3 followed by T4 (0.98%), T1 (0.95%) and T2 (0.925%). The residues incorporation and zero tillage significantly contributed to soil phosphorus (by 0.02-0.03 ppm), potassium (by 5 ppm) and organic matter (by 0.02%). Contrarily, the residues burning practice reduced the soil potassium (by 1 ppm) and organic matter (by 0.01%). At the same time, soil nitrogen was noted as highest proportion (0.1%) for T3, followed by T4 (0.09%), T1 (0.085%) and T2 (0.075%), respectively. Potassium contents were also significantly improved in given treatments with same hierarchy. However, practicing the residues incorporation and zero tillage method, phosphorus contents were improved but insignificantly.

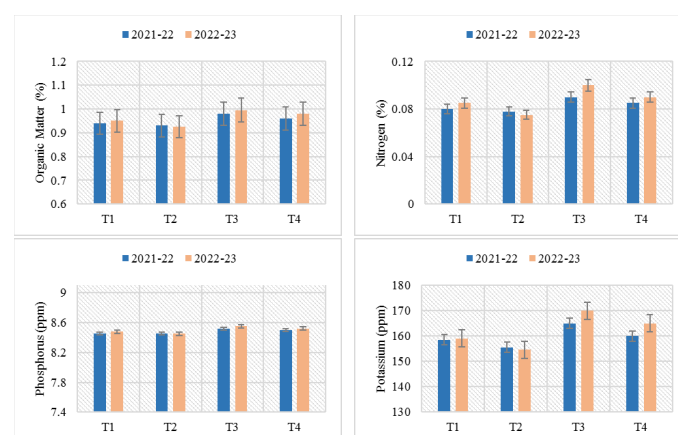


Figure 6: Treatment effects on soil organic matter and NPK.

The results are in accordance to the findings of literature. A significant volume of nutrients in rice-wheat cropping system can be recycled by managing the rice residues appropriately (Hung *et al.*, 2019). The practice of residues burning causes significant loss of nutrients i.e., Nitrogen, Phosphorus and Potassium (NPK) into soil, (Fairhurst *et al.*, 2007; Jain *et al.*, 2014; Hung *et al.*, 2019). On the other hand, the practice of incorporating rice residues into soil leads to the improvement of soil structure and organic matter as well as NPK concentration levels (Fairhurst *et al.*, 2007; Singh *et al.*, 2008). Rice crop residues may serve as effective substitute for chemical fertilizers, and satisfying the demand for crop nutrients through the practice of residues incorporation may lead to the substantial decline in import-requirements of chemical fertilizers (Zhao *et al.*, 2009; Tran and Hung, 2010; Hung *et al.*, 2019;

Keck and Hung, 2019). It would help improving the trade balance of country through reduced demand for imports of costly fertilizers (Bui, 2008). Farmers' net income can also be increased by less investment into inorganic fertilizers (Baumann, 2014). Similarly, less or zero tillage practice promotes carbon sequestration which improves organic carbon into soil by significant proportion (Liu *et al.*, 2014; Cooper *et al.*, 2021). Haddaway *et al.* (2017) conduct a systematic review and conclude that zero tillage significantly conserves the soil carbon as compared to conventional tillage and ultimately improves the biological activity as well as delivers strength to crops against extreme weather conditions.

Conclusions and Recommendations

Study investigates the role of different rice-residues management practices for improving wheat productivity as well as soil health. The field trial (based on two years) compares the eco-friendly residues management practices (residues incorporation and zero tillage) with environment degrading conventional practice of rice-stubbles burning into fields. The results suggest that rice-residues incorporation practice offers highest wheat yield per hectare followed by zero tillage practice (using happy seeder) and then conventional practice (residues burning), respectively. While observing the parameters other than grain yield, it was found that number of grains per spike and thousand grains weight in the field of conventional practice were slightly greater than other treatments but with insignificant differences. Similarly, it is found that use of zero tillage and residues incorporation practices improve soil nutrients levels i.e., organic matter and NPK concentration. The empirical findings conclude that conservation agriculture practices can perform at least equally to or better than conventional (farmers') practice of rice-residues burning in terms of subsequent wheat yield and soil health. The study results advocate practicing the zero or less tillage technique for wheat sowing after harvesting of rice in order to economize agricultural production, conserve natural resources and minimize the soil degradation caused by burning of rice residues. Although there are more weeds in zero tillage sowing as compared to the conventional practice, but it could be controlled by the proper use of weedicides. The practice of burning the rice residues (farmers' practice) may be discouraged as it has negative effect on soil properties and overall environment. Similarly, heavy tillage machinery

can disturb the soil structure and texture, and may create hard pan under the soil crest thereby causing the infiltration problems. Zero tillage practice is better substitute to sow the wheat followed by rice crop without any hazards except weeds problem. The appropriate and timely use of weedicides may be promoted to tackle the weeds problem.

Acknowledgments

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Novelty Statement

This study is the first of its kind in Sargodha region of Punjab, Pakistan, to evaluate and compare the impact of rice residue management practices on wheat yield and soil health over a multi-year period. The findings not only highlight significant improvements in soil nutrient retention and carbon sequestration but also emphasize cost reductions and environmental benefits, providing a guideline for adopting sustainable practices in the rice-wheat cropping system.

Author's Contribution

Ammara Khan, Ishtiaq Hassan and Ali Raza: Conceptualized the study.

Ammara Khan, Khalid Mehmood and Ayesha Sultana: Performed methodology, formal analysis and investigation.

Ammara Khan and Ali Raza: Wrote original first draft.

Khalid Mehmood, Ishtiaq Hassan and Ayesha Sultana: Reviewed, edited and finalized the manuscript.

All authors read and approved the final manuscript.

Conflict of interest

The authors have declared no conflict of interest.

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