Research Article

Optimizing Maize Residue Levels and Application Methods with Co-Application of Waste Decomposer for Enhancing Wheat Productivity

Muhammad Numan[1*], Abbas Saleem[1], Muhammad Arif[1], Muhammad Ahmad Saleem[1,2], Muhammad Nouman Khan[1], Haris Ahmad[1], Muhammad Abbas[1] and Syed Mahad Ali Sha Gillani[3]

[1]Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar; [2]College of Coastal Agricultural Sciences, Guangdong Ocean University, Zhanjiang, China; [3]Department of Botany, Islamia College Peshawar.

Abstract | Wheat production in Pakistan is often limited by poor soil fertility and inefficient nutrient management, especially in cereal-based cropping systems. This study aimed to determine the optimal combination of maize residue management and waste decomposer application to improve wheat growth, yield, and soil fertility. The experiment was conducted at the Agronomy Research Farm, The University of Agriculture Peshawar, during the winter of 2023–24. Maize residue levels were assigned to the main plots (control, 50% residue incorporated, 50% residue as mulch, 100% residue incorporated, and 100% residue as mulch), and waste decomposer was applied to the subplots (control and 500 L ha^{-1}). Sowing was done on 18th November 2023 using the Gulzar-2019 variety at the rate of 120 kg ha^{-1}. Results indicated that the 100% maize residue as mulch significantly improved wheat performance, producing the highest grain yield (3484 kg ha^{-1}), biological yield (13118 kg ha^{-1}), and number of spikes m^{-2} (310). Similarly, the application of waste decomposer at 500 L ha^{-1} enhanced yield and yield components compared to the control.

Received | September 17, 2025; **Accepted** | February 10, 2026; **Published** | August 13, 2026
***Correspondence** | Muhammad Numan, Department of Agronomy, Faculty of Crop Production Sciences, The University of Agriculture, Peshawar; **Email:** numanmuhammad268@gmail.com
Citation | Numan, M., A. Saleem, M. Arif, M.A. Saleem, M.N. Khan, H. Ahmad, M. Abbas and S.M.A.S. Gillani. 2026. Optimizing maize residue levels and application methods with co-application of waste decomposer for enhancing wheat productivity. *Sarhad Journal of Agriculture*, 42(4): 1424-1432.
DOI | https://dx.doi.org/10.17582/journal.sja/2026/42.4.1424.1432
Keywords | Maize residue management, Waste decomposer, Mulching, Wheat yield, Soil fertility

Introduction

Wheat (*Triticum aestivum* L.) belongs to the Poaceae family and is one of the most important staple food crops globally (Anwaar *et al*., 2020). Pakistan ranks as the eighth-largest wheat producer in the world, with approximately 42% of its total arable land dedicated to wheat cultivation (Sher *et al*., 2022). In 2024, Pakistan produced 31.4 million tons of wheat from 9.632 million hectares, achieving a record average yield of 3.26 tons ha^{-1} (Yaseen *et al*., 2025). However, productivity in Khyber Pakhtunkhwa remained relatively low, with an average yield of 1.9 t ha^{-1} from 0.75 million hectares (Ambreen *et al*., 2025). Despite its significance, the country's average yield remains low compared to major wheat-producing nations (Kakar, 2015). Wheat is a crucial dietary component, with more than 70% of the global population consuming it daily (Rizwan *et al*., 2017). However, continuous use of chemical fertilizers has led to soil degradation and declining productivity. Among the unsustainable practices, burning crop residues has contributed to the loss of valuable organic matter and essential nutrients, including nitrogen (N), phosphorus (P), and sulfur (S), in the soil. In contrast, returning crop residues to the soil is considered an effective strategy for improving soil fertility and enhancing crop productivity (Choudhary *et al*., 2018). Crop residues incorporation plays a vital role in sustainable agriculture by conserving soil structure and nutrient balance (Xu *et al*., 2018). When incorporated into the soil, organic residues help maintain soil fertility and promote nutrient availability (Chen *et al*., 2019; Dai *et al*., 2013). Studies have shown that crop residue application enhances plant growth and yield by improving the availability, concentration, and uptake of primary nutrients such as nitrogen, phosphorus, and potassium (Jiang *et al*., 2019; Sui *et al*., 2015), ultimately enhancing soil tilth and overall productivity. Cereal straw is one of the primary organic inputs used in conservation agriculture, enriching the soil with organic matter, boosting microbial life, and improving the soil's biological functions (Sendetsky, 2018). Microbial waste decomposers accelerate the breakdown of complex organic materials like cellulose, promoting the activity of beneficial soil microbes and suppressing harmful pathogens (Zhan, 2024). Microbial waste decomposers have emerged as an eco-friendly alternative to conventional residue management practices. These formulations accelerate the breakdown of complex organic compounds such as cellulose, thereby enhancing nutrient cycling and promoting the activity of beneficial soil microbes while suppressing soil-borne pathogens (Zhou *et al*., 2025). Waste decomposer is a consortium of beneficial microorganisms, including *Lactobacillus spp.*, *Bacillus subtilis*, *Bacillus megaterium*, *Pseudomonas fluorescens*, *Azotobacter spp.*, phosphobacteria, and yeasts (*Saccharomyces spp.*), which work synergistically to decompose organic matter, improve nutrient availability, and enhance soil health and crop productivity (Kora, 2022). The application of waste decomposers has been shown to significantly increase microbial biomass (by 3–5 t ha^{-1}), stimulate nutrient mineralization, and restore soil fertility more efficiently than traditional methods like residue burning or deep tillage (Panfilova, 2021). Furthermore, they have demonstrated potential in increasing crop yields by 10–30% and reducing dependency on synthetic fertilizers, thereby contributing to sustainable and cost-effective farming systems (Panfilova, 2021; Sendetsky, 2019). The objective of this study was to evaluate the effect of integrated maize residue management and waste decomposer application on the growth and productivity of wheat under the maize–wheat cropping system.

Materials and Methods

Research site

In the winter of 2023-2024, a field experiment was carried out at the Agriculture University Peshawar's Agronomy Research Farm. The average summer temperature at the research location was 40°C (May to September), while the average winter temperature was 25°C (December to the end of March). The climate was semi-arid and subtropical. The area receives 360 mm of rainfall yearly, with the majority of winter rainfall occurring in winter (Iqbal and Ali, 2022) (Figure 1).

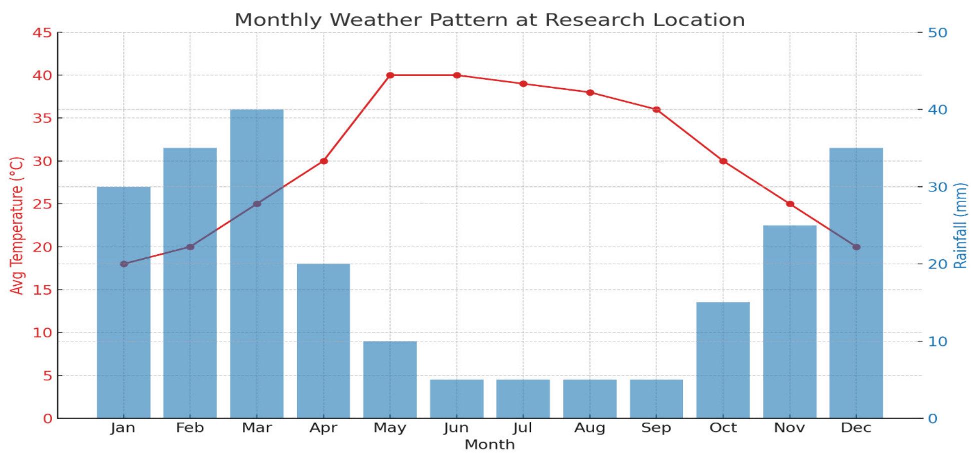

Figure 1: *Average monthly temperature and rainfall pattern at the experimental site under semi-arid and subtropical climate conditions.*

Soil analysis (before sowing)

Before sowing, composite soil samples were collected from the experimental field and analyzed for physico-chemical properties (Table 1). Soil texture (%) was determined by the hydrometer method (Bouyoucos, 1951), while bulk density was measured using undisturbed soil cores (Sahlemedhin and Taye, 2000). Soil pH (1:2.5 soil–water suspension) and electrical conductivity were measured potentiometric ally (Jackson, 1973). Organic matter (%) was determined by the Walkley–Black method (Walkley and Black, 1934). Total nitrogen was analyzed using the Kjeldahl method (Jackson, 1973). Available phosphorus was determined by the Olsen method (Olsen *et al*., 1954) and available potassium was extracted with 1 N ammonium acetate and measured using a flame photometer (Jackson, 1973).

Table 1: *The physico-chemical properties of the experimental soil.*

Soil Property	Value
Soil texture	Silt loam
pH	8
Electrical conductivity (EC)	0.85 dS m^{-1}
Organic matter	0.78%
Total nitrogen (N)	0.04%
Available phosphorus (P)	6.4 mg kg^{-1}
Available potassium (K)	130 mg kg^{-1}
Bulk density	1.24 g cm^{-3}

Treatment details

For the experiment, a wheat-maize cropping system was followed, which had been continuously practiced for the last three years. Maize crop residue was managed in four different ways: the biomass produced by maize crops (except grains) was retained in the field in the form of crop residue as 50% (7.5 t ha^{-1}) and 100% (15 t ha^{-1}) incorporated, and 50% and 100% mulching. Two levels of waste decomposer (0 and 500 L ha^{-1}) were applied at the tillering and booting stages. The solution was prepared by dissolving 2 kg of jaggery in 200 L of clean water in a plastic drum, followed by the addition of 30 g of waste decomposer culture. The mixture was stirred thoroughly, covered with a breathable cloth to permit gas exchange, and allowed to ferment for 7 days with daily stirring to ensure microbial activation. The fermented solution was applied using a hand-operated knapsack sprayer at the rate of 500 L ha^{-1}. All agronomic practices, including land preparation, fertilization, and irrigation, were uniformly applied throughout the experimental field.

Experimental design

The experiment was laid out using a randomized complete block design (RCBD) with a split-plot arrangement, consisting of main plots with crop residue management (RM) and subplots with waste decomposer (WD), with four replications. The plot measuring 4.2 m x 4 m (16.8 m^2) was used. The wheat variety Gulzar-2019 was sown on the 18th November at a seed rate of 120 kg ha^{-1} with row-to-row spacing of 30 cm, maintaining fourteen rows in each subplot.

The data on seven key parameters, including days to physiological maturity, plant height (cm), spikes m^{-2}, number of grains $spike^{-1}$, thousand-grain weight (g), biological yield (kg ha^{-1}), and grain yield (kg ha^{-1}), were recorded.

Statistical analysis

For the statistical analysis of the collected data, the ANOVA method was applied to the RCB split-plot design. Following a significant F-test, means were compared using the least significant differences (LSD) test at $P < 0.05$ (Jan *et al*., 2009).

Results and Discussion

Days to physiological maturity

Wheat physiological maturity was significantly affected by residue management, while waste decomposer and their interaction showed no significant effects (Table 2). The maximum days to maturity (160.3 days) were recorded with 15 t ha^{-1} residue as mulch, followed by 15 t ha^{-1} incorporated (159.8), 7.5 t ha^{-1} mulch (159.8), and 7.5 t ha^{-1} incorporated (159.0). The shortest maturity period (158.9 days) was observed in control plots. The application of waste decomposer (WD) had no significant effect, with a slight decrease in DTPM from 159.6 (no WD) to 159.4 (WD at 500 L ha^{-1}).

The slight delay in maturity under full mulching could be attributed to improved soil moisture and moderated soil temperature, which prolongs the photosynthetic phase and enhances assimilate availability during grain filling. This is supported by Ali (2015), who found that mulch-based residue management extended the phenological stages of wheat due to improved soil-water balance and microclimate regulation.

Plant height (cm)

Plant height was significantly affected by both residue management and waste decomposer application, while the interaction was not significant (Table 2). The tallest plants (87.6 cm) were observed in 15 t ha^{-1} mulch, followed by 15 t ha^{-1} incorporation (85.2 cm), 7.5 t ha^{-1} mulch (84.1 cm), and 7.5 t ha^{-1} incorporation (81.1 cm). The shortest plants were found in the control plots (73.1 cm). The waste decomposer significantly increased plant height from 79.4 cm (no WD) to 85.1 cm (WD at 500 L ha^{-1}).

Table 2: *Residue management and waste decomposer were significantly influenced by DTA, DTPM, PH, NSPMS, and NGPS.*

Residue Management (ton ha^{-1})	**DTPM**	**PH**	**NSPMS**	**NGPS**
Control	158.9	73.1	270	50
7.5	159.0	81.1	284	54
7.5	159.8	84.1	297	57
15	159.8	85.2	304	58
15	160.3	87.6	310	59
LSD	0.94	6.25	23.1	5.72
Waste decomposer (L ha^{-1})				
0	159.6	79.4	286	54
500	159.4	85.1	300	57
LSD		3.95		

DTPM (days to physiological maturity), PH (plant height), NSPMS (number of spikes m^{-2}), NGPS (number of grains $spike^{-1}$)

This improvement in plant stature is likely due to better soil structure, moisture availability, and nutrient dynamics created by surface mulch and microbial enhancement from waste decomposer. Dhar *et al.* (2014) and Feizabady (2013) also reported similar findings, attributing enhanced plant height to improved soil physical conditions and nutrient release under straw and residue retention strategies. Microbial decomposers further accelerate residue breakdown, improving nitrogen availability and plant growth (Sahu *et al.*, 2017).

Number of spikes m^{-2}

Residue management had a significant effect on spike density, while waste decomposer and interactions were non-significant (Table 2). The highest spike count (310 m^{-2}) was observed under 15 t ha_{-1} mulch, followed by 15 t ha_{-1} incorporation (304), 7.5 t ha^{-1} mulch (297), 7.5 t ha^{-1} incorporated (284), and control (275). Waste decomposer at 500 L ha^{-1} marginally increased spike number (300) over untreated plots (286).

The increased spike density under mulch treatments could be linked to favorable soil moisture levels and decreased weed pressure, which allows for higher tiller survival. According to Feizabady (2013), returning 100% of crop residues improved spike production due to consistent nutrient availability and enhanced tillering. Decomposer use may also boost microbial activity, promoting nitrogen release that supports spike differentiation.

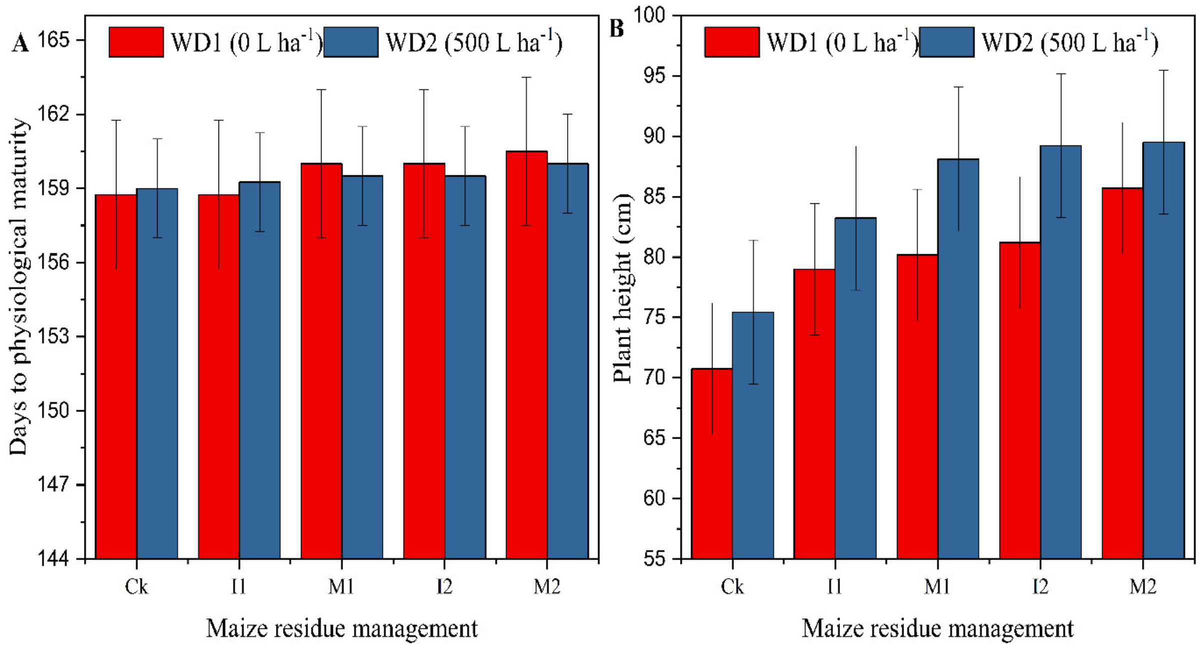

Figure 2: *Impact of maize residue management and waste decomposer use on days to physiological maturity and plant height (cm).*

Number of grains spike^{-1}

Residue management had a significant influence on grains per spike, while waste decomposer and their interactions had no significant impact (Table 2). The highest number of grain spikes^{-1} was recorded under 15 t ha^{-1} mulch (59), followed by 15 t ha incorporation (58), 7.5 t ha^{-1} mulch (57), 7.5 t ha^{-1} incorporation (54), and control (50). The waste decomposer application resulted in a slight improvement in grains per spike (57) compared to untreated plots (54).

The improvement may stem from better soil nutrient retention and increased reproductive efficiency due to mulching. Kamkar *et al.* (2014) also observed higher spike fertility under residue retention, attributing it to improved source-sink relationships and a longer grain filling period.

Thousand-grain weight (g)

Both residue management and waste decomposer significantly influenced TGW, with no interaction effect (Table 3). The heaviest grains (49.9 g) were recorded in 15 t ha^{-1} mulch, followed by 15 t ha^{-1} incorporated (46.5 g), 7.5 t ha^{-1} mulch and incorporation (45.3 g), and the control (44.0 g). Waste decomposer at 500 L ha^{-1} produced heavier grains (47.7 g) compared to untreated plots (44.7 g).

Improved TGW under residue and decomposer treatments may be linked to sustained soil moisture during grain filling, ensuring better translocation of assimilates. This aligns with (Kamkar *et al.*, 2014) and (Bakht *et al.*, 2009), who reported that mulch and organic inputs enhance grain development by optimizing nutrient availability and water retention. Bio-fertilizers like waste decomposer further aid nutrient mineralization and improve grain density (Attia and Barsoum, 2013).

Biological yield (kg ha^{-1})

Significant effects of residue management and waste decomposer on biological yield were observed (Table 3). The highest BY (13,118 kg ha^{-1}) was achieved with 15 t ha^{-1} mulch, followed by 15 t ha^{-1} incorporated (12,677), 7.5 t ha^{-1} mulch (12,360), 7.5 t ha^{-1} incorporated (12,165), and the lowest in control plots (11,853). Waste decomposer at 500 L ha^{-1} increased BY (12,679) compared to no WD (12,191).

Table 3: *Residue management and waste decomposer were significantly influenced by TGW, BY and GY.*

Residue Management (ton ha^{-1})	TGW	BY	GY
Control	44	11853	3057
7.5	45.3	12165	3078
7.5	45.3	12360	3246
15	46.5	12677	3345
15	49.9	13118	3484
LSD	3.9	759.5	235.5
Waste decomposer (L ha^{-1})			
0	44.7	12191	3165
500	47.7	12679	3318
LSD	2.5	480.4	149

TGW (thousand grains weight), BY (biological yield), GY (grain yield)

The enhanced BY is likely the result of improved canopy structure, chlorophyll retention, and vegetative

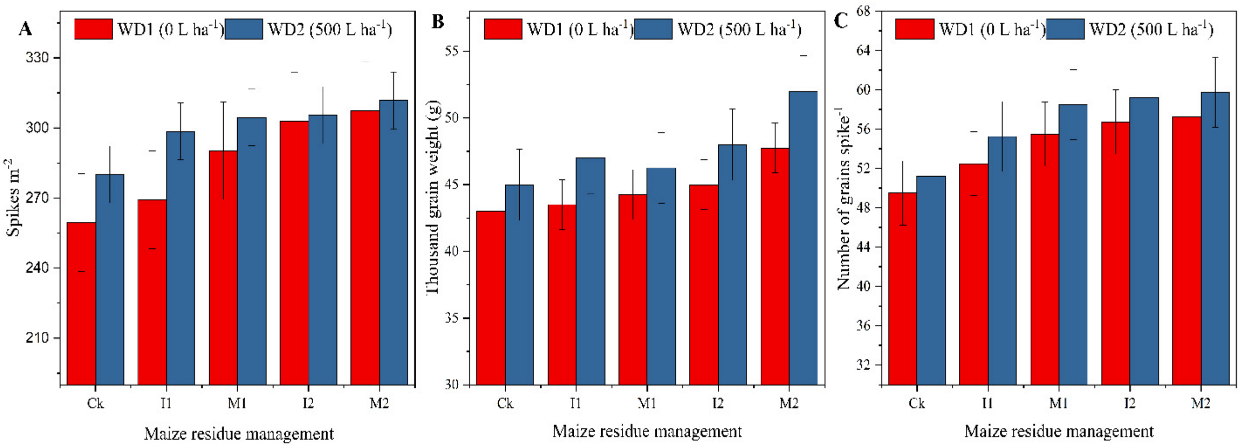

Figure 3: *Impact of maize residue management and waste decomposer use on spikes per square meter, grains per spike, and thousand-grain weight (g) of wheat.*

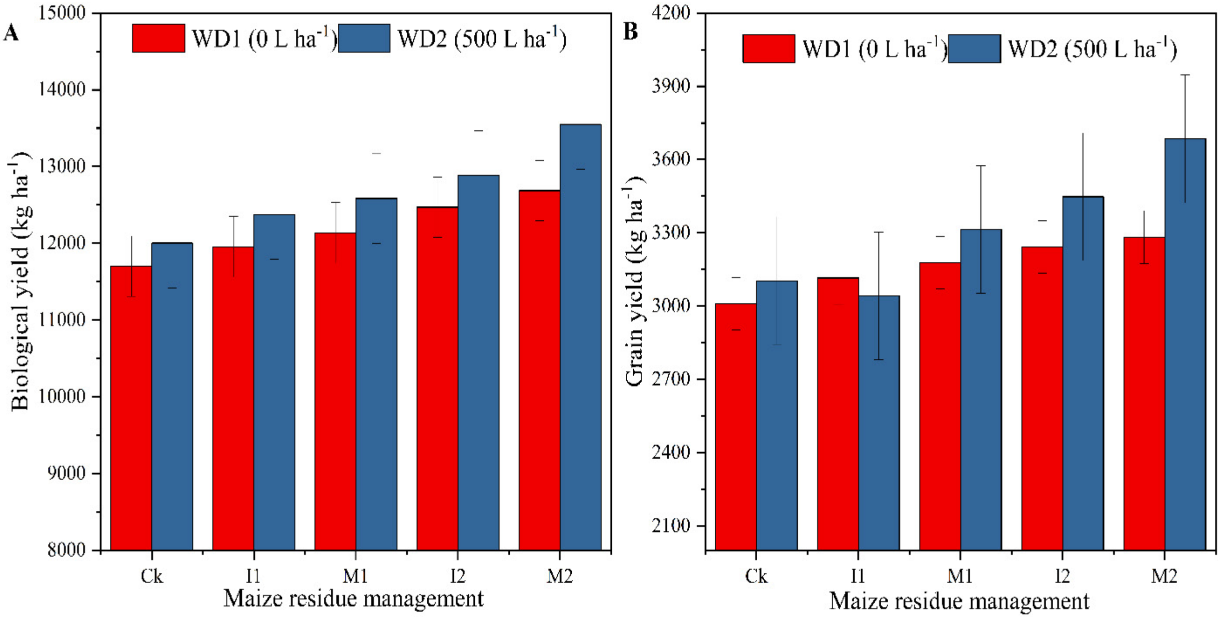

Figure 4: *Impact of maize residue management and waste decomposer use on biological and grain yield.*

biomass accumulation under mulch and decomposer treatments. Similar results were reported by Aslam *et al*. (2021), who found that maize residue mulch significantly increased wheat BY. (Hussein *et al*., 2022) It was also confirmed that increasing residue levels significantly improves total biomass due to improved nutrient availability.

Grain yield (kg ha-1)

Grain yield was significantly influenced by both residue management and waste decomposer application (Table 3). The highest GY (3484 kg ha^{-1}) occurred at 15 t ha^{-1} mulch, followed by 15 t ha^{-1} incorporation (3345), 7.5 t ha^{-1} mulch (3246), 7.5 t ha^{-1} incorporation (3078), and control plots (3057). Waste decomposer at 500 L ha^{-1} enhanced yield (3318) compared to no WD (3165).

The increased grain yield can be attributed to improvements in all yield components, particularly grain number and grain weight. The application of crop residues plays a vital role in enhancing soil fertility and water retention, which in turn promotes nutrient uptake and efficient grain filling. (Kamkar *et al*., 2014) reported comparable yield advantages under full residue application. Although the effect was relatively modest, the application of waste decomposer contributed to nutrient cycling and soil microbial activity, ultimately improving grain yield. This observation aligns with the findings of Panfilova (2021), who documented increased wheat yields following the application of microbial decomposers.

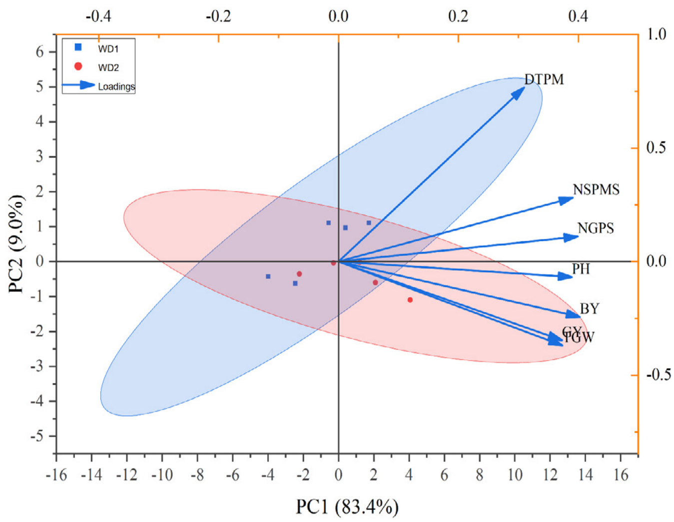

Figure 5: *Principal component analysis (PCA) biplot showing the relationship among wheat growth and yield traits.*

The PCA biplot revealed a clear separation between the two waste decomposer treatments, with PC1 accounting for the majority of the variation (83.4%) shown in Figure 2. Traits such as grain yield (GY), biological yield (BY), and thousand grain weight (TGW) exhibited strong positive associations with PC1, contributing significantly to treatment differentiation. WD2 treatments were clustered along the positive axis of PC1, indicating their favorable influence on key yield and growth attributes. This multivariate approach underscores the superior performance of WD2 in enhancing wheat productivity.

Links Researchers

Conclusions and Recommendations

The study concluded that the integration of crop residue management significantly enhanced wheat yield and soil health, particularly when combined with waste decomposer application. Incorporating wheat residue along with waste decomposer proved most effective in improving crop performance. It is recommended that farmers adopt this integrated approach to sustainably increase wheat productivity and maintain soil fertility under similar agroecological conditions.

Acknowledgments

The authors are gratekful to the Department of Agronomy, the University of Agriculture, Peshawar-Pakistan for its support during this research study.

Novelty Statement

Wheat yield and soil health improved with the application of wheat residue retention and waste decomposer, indicating the potential of integrated residue management for sustainable wheat production.

Author's Contribution

Muhammad Numan: Carried out research and drafted the manuscript.
Abbas Saleem: Helped in layout of the research.
Muhammad Arif: Conceived the idea and supervised the research.
Muhammad Ahmad Saleem: Helped in data collection.
Muhammad Nouman Khan: Helped in data collection.
Haris Ahmad: Helped in data analysis.
Muhammad Abbas: Helped in data collection.
Syed Mahad Ali Sha Gillani: Helped in data collection.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

References

Ali, S. 2015. Effect of humic acid and crop residue application on emergence and wheat phenology. Pure and Applied Biology.

Ambreen, M., K. Fawad, Y. Samina, A.K. Imtiaz, M. Farhanda and U. Inam. 2025. Population of wheat aphid (Rhopalosiphum padi L.) and it's associated natural enemies. Insights-J. Life Social Sci., 3(2):147–155. https://doi.org/10.71000/aj68vb20

Anwaar, H.A., R. Perveen, M.Z. Mansha, M. Abid, Z.M. Sarwar, H.M. Aatif, U. Umar, M. Sajid, H.M.U. Aslam and M.M. Alam. 2020. Assessment of grain yield indices in response to drought stress in wheat (Triticum aestivum L.). Saudi J. Biol. Sci., 27(7): 1818–1823. https://doi.org/10.1016/j.sjbs.2019.12.009

Aslam, M.U., M.U. Chattha, I. Khan, R. Maqbool, M.B. Chattha, F. Hussan, M. Nawaz, M.S. Hanif, M.A. Ayub, and M.T. Aslam. 2021. Effect of different organic mulches and nitrogen sources on the productivity of wheat crop grown in semi-arid area. https://doi.org/10.17582/journal.pjar/2021/34.3.648.655

Attia, M. and M. Barsoum. 2013. Effect of supplementary irrigation and bio-fertilization on wheat yield productivity under rainfed conditions. Alex. J. Agric. Res., 58(2): 149–157.

Bakht, J., M. Shafi, M.T. Jan, and Z. Shah. 2009. Influence of crop residue management, cropping system and N fertilizer on soil N and C dynamics and sustainable wheat (Triticum aestivum L.) production. Soil Tillage Res., 104(2): 233–240. https://doi.org/10.1016/j.still.2009.02.006

Buoyoucos, G.H. 1951. Reclamation of the hydrometer for marking mechanical analysis of soil. Agron. J., 43: 434-438. https://doi.org/10.2134/agronj1951.00021962004300090005x

Chen, J., Y. Gong, S. Wang, B. Guan, J. Balkovic, and F. Kraxner. 2019. To burn or retain crop residues on croplands? An integrated analysis of crop residue management in China. Sci. Tot. Environ., 662: 141–150. https://doi.org/10.1016/j.scitotenv.2019.01.150

Choudhary, M., A. Datta, H.S. Jat, A.K. Yadav, M.K. Gathala, T.B. Sapkota, A.K. Das, P.C. Sharma, M.L. Jat, R. Singh and J.K. Ladha. 2018. Changes in soil biology under conservation agriculture based sustainable intensification of cereal systems in Indo-Gangetic Plains. Geoderm., 313: 193–204. https://doi.org/10.1016/j.geoderma.2017.10.041

Dai, X., Y. Li, Z. Ouyang, H. Wang and G.V. Wilson. 2013. Organic manure as an alternative to crop residues for no-tillage wheat–maize systems in North China Plain. Field Crop. Res., 149: 141–148. https://doi.org/10.1016/j.fcr.2013.04.027

Dhar, D., A. Datta, N. Basak, N. Paul, S. Badole, and T. Thomas. 2014. Residual effect of crop residues on growth, yield attributes and soil properties of wheat under rice-wheat cropping system. Ind. J. Agric. Res., 48(5): 373–378. https://doi.org/10.5958/0976-058X.2014.01317.1

Feizabady, A.Z. 2013. Effects of crop rotation and residue management on bread wheat. Afr. J. Plant Sci., 7: 176–184. https://doi.org/10.5897/AJPS12.081

Hussein, M., M. Ali, M.H. Abbas and M.A. Bassouny. 2022. Composting animal and plant residues for improving the characteristics of a clayey soil and enhancing the productivity of wheat plant grown thereon. Egypt. J. Soil Sci., 62(3): 195–208. https://doi.org/10.21608/ejss.2022.154465.1524

Iqbal, B. and M. Ali. 2022. Estimation of spatio-temporal air temperature from satellite based LST under semi-arid to arid environment in Peshawar Basin, Northwest Pakistan. Advan. Space Res., 70(4): 961-975. https://doi.org/10.1016/j.asr.2022.05.052

Jackson, M.L. 1973. Soil chemical analysis. pp. 528. In: Prentice Hall Inc., Englewood Cliffs. John Wiley Sons, New York, NY.

Jan, M., P. Shah, P. Hollington, M. Khan and Q. Sohail. 2009. Agriculture research: Design and analysis, a monograph. NWFP Agric. Univ. Pesh. Pak., 1: 232.

Jiang, N., B. Hu, X. Wang, Y. Meng, B. Chen and Z. Zhou. 2019. Effects of crop residue incorporation and inorganic potassium fertilization on soil potassium supply power. Archiv. Agron. Soil Sci., 65(9): 1223–1236. https://doi.org/10.1080/03650340.2018.1562174

Kakar, K.M. 2015. Effect of irrigation levels and bed-system of planting on seed fill duration, seed growth rate, yield and yield components of spring wheat (Triticum aestivum) under semiarid condition. Pure Appl. Biol., 4(4): 511–521. https://doi.org/10.19045/bspab.2015.44009

Kamkar, B., F. Akbari, J. Silva and S. Naeini. 2014. The effect of crop residues on soil nitrogen dynamics and wheat yield. Advan. Plants Agric. Res., 1(1): 1–7. https://doi.org/10.15406/apar.2014.01.00004

Kora, A.J. 2022. Applications of waste decomposer in plant health protection, crop productivity and soil health management. In Applic. Microb. Environ. Microbial Biotechnol., (pp. 609–624). Springer. https://doi.org/10.1007/978-981-16-2225-0_22

Olsen, S.R., C.V. Cole, F.S. Watanabe and L.A. Dean. 1954. Estimation of available phosphorus in soils by extraction with sodium carbonate. USDA, Circ., 939:1–19.

Panfilova, A. 2021. Influence of stubble biodestructor on soil microbiological activity and grain yield of winter wheat (Triticum aestivum L.). Notulae Sci. Biol., 13(4): 11035–11035. https://doi.org/10.15835/nsb13411035

Rizwan, M., J.N. Chauhdary, U.D. Khan and M. Arsalan. 2017. Effects of different tillage implements on the growth and yield of wheat in cotton-wheat zone of Pakistan. Pak. J. Life Soc. Sci., *15*: 7–10.

Sahlemedhin, S. and B. Taye. 2000. Procedure for soil and plant analysis. National Soil Research Centre, Ethiopian Agricultural Research Organization, Addis Ababa, Pp. 110.

Sahu, A., K. Verma, A. Teta and L. Karumuri. 2017. Effect of compost derived from decomposed kitchen waste by microbial decomposers on plant growth parameters of crops. J. Pharmacog. Phytochem., *6*(3): 435–438.

Sendetsky, V. 2018. Economic efficiency of growing soi depending on the application of organic components. Наукові Горизонти., 1: 64–69. https://doi.org/10.33249/2663-2144-2018-64-1-64-69

Sendetsky, V. 2019. Crop yields and quality indicators of corn under joint application of straw and green manure. Taurian Sci. Bullet., 105: 147–154.

Sher, A., B. Sarwar, A. Sattar, M. Ijaz, S. Ul-Allah, M.T. Hayat, A. Manaf, A. Qayyum, A. Zaheer and J. Iqbal. 2022. Exogenous application of zinc sulphate at heading stage of wheat improves the yield and grain zinc biofortification. Agron., 12(3): 734. https://doi.org/10.3390/agronomy12030734

Sui, N., Z. Zhou, C. Yu, R. Liu, C. Yang, F. Zhang, G. Song and Y. Meng. 2015. Yield and potassium use efficiency of cotton with wheat straw incorporation and potassium fertilization on soils with various conditions in the wheat–cotton rotation system. Field Crop. Res., 172: 132–144. https://doi.org/10.1016/j.fcr.2014.11.011

Walkley, A. and I.A. Black. 1934. An examination of the Degtjareff method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci., 37: 29–38. https://doi.org/10.1097/00010694-193401000-00003

Xu, X., D. Pang, J. Chen, Y. Luo, M. Zheng, Y. Yin, Y. Li and Z. Wang. 2018. Straw return accompany with low nitrogen moderately promoted deep root. Field Crops Res., 221: 71–80. https://doi.org/10.1016/j.fcr.2018.02.009

Yaseen, I., A. Yaqoob, S.K. Hong, S.B. Ryu, H.S. Mun and H.T. Kim. 2025. A Sustainable Approach for Assessing Wheat Production in Pakistan Using Machine Learning Algorithms. Agron., 15(3): 654. https://doi.org/10.3390/agronomy15030654

Zhan, C. 2024. Microbial decomposition and soil health: Mechanisms and ecological implications. Molecul. Soil Biol., 15. https://doi.org/10.5376/msb.2024.15.0007

Zhou, X., Y. Yan, Y. Li, L. Liu, J. Zhou, C. Dai, Z. Cai and X. Huang. 2025. Application of cellulose-rich organic resource improves soil quality and plant growth by recruiting beneficial microorganisms. Appli. Soil Ecol., 207: 105909. https://doi.org/10.1016/j.apsoil.2025.105909