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Impact of Biomass Recycling and Fertilization on Soil Microbiological Characteristics and Wheat Productivity in Semi-Arid Environment

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Abstract: In India, 700 million tons of agricultural waste generated annually is burned by farmers in the fields, which decreases biological activity in soil. The issue of handling the enormous amounts of crop residues that emerge from increased crop output might be resolved by composting. However, different crop residues improve soil physico-chemical and biological properties in different ways. Crop residue incorporation and fertilization (NPK) impact crop productivity due to changes in soil microbial biomass carbon, nitrogen, phosphorous, and the soil enzymatic activity. A field experiment was conducted for two years (2020–2021 and 2021–2022), which comprises five partially composted crop residues treatments viz., control, clusterbean straw, groundnut shell, pearlmillet husk, and sesame stover (added at rate of 5 t ha^{-1}), and four fertilization (NPK) treatments viz., control, 75% RDF, 100% RDF, and 125% RDF. The microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), microbial biomass phosphorus (MBP), enzymatic activities in soil and wheat yield were studied under a semi-arid environment (India). Data showed that the continuous application of crop residues and fertilizer significantly affected MBC, MBN, MBP, and soil enzymatic activity after two years of experimentation in a semi-arid region environment. The highest levels of microbial biomass (viz, MBC, MBN, MBP) and enzyme activities were noticed in the sesame stover and 125% recommended dose of fertilizer (RDF) treatments. Therefore, this study highlights the need for restoring crop residue for effective soil management. The crop residue and NPK fertilization are more efficient in improving the soil's microbial properties and the yield of wheat.

Keywords: crop residue; microbial biomass nitrogen; C:N ratio; microbial biomass carbon; microbial biomass phosphorous and dehydrogenase; alkaline phosphatase enzymatic activity

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1. Introduction

Soil and crop management practices such as fertilization, crop rotation, and land-use change exert a considerable influence on soil chemical and biological properties over time [1–3]. Routine applications of inorganic fertilizer [4] and manure are an essential component of soil management in arable crop production systems [5–7]. Although the main purpose of these amendments is to make more nutrients available to plants [8–10], it may also affect the microbial population of the soil [11–13]. More people are becoming aware of the advantages of utilizing organic manure and crop residues to maintain soil quality [14]. The long-term sustainability of agricultural systems depends on soil microorganisms [15–18] and the activities they govern [19]. Soil microorganisms are important factors for the development of soil and nutrient cycling. It has been noted often that microbial activity and their biomass in the soil are an essential part of soil quality [20,21]. Research has demonstrated that crop and soil management strategies, such as the use of organic manure and inorganic fertilizers, crop rotation [22], tillage [23–25], and land-use change, have an impact on the microbial biomass and activity [26]. Dehydrogenases are one of the most significant enzymes in the soil environment, and because they occur intracellularly in all living microbial cells [27], they are utilized as an indicator of overall soil microbial activity [28]. Dehydrogenases transfer hydrogen from organic substrates to inorganic acceptors, which is a crucial step in the biological oxidation of soil organic matter (SOM) [29]. Phosphatase enzymes released by plants and microorganisms contribute to the cleavage of organic P in order to supply available P to the soil solution [30]. A large proportion of the nutrient transformations occurring in the soil is achieved by soil enzymes [31]. The soil quality and microbial activity in soil are considered to be predominantly impacted by enzyme activities in the soil environment [32,33].

Nutrient cycling is an important aspect of the relationship between soil microorganisms and agricultural production [34–38], and the quantity of soil microorganisms significantly affects the organic matter turnover [39,40]. Inorganic fertilizers have several advantages of maintaining crop yields [41–46] and soil biodiversity while optimizing soil properties, i.e., physical, chemical, and biological properties [47]. In the top layer of soil beneath grazing and pasture land, the majority of the organic matter is comprised of nitrogen and organic carbon [48]. Both the production of organic matter and the availability of the aggregates needed for agricultural purposes mainly depend on soil microorganisms and their biomass [49]. They are responsible for mobilizing the plant's available nutrients, absorbing them, mineralizing them, and recycling the microbial biomass and crucial components of C:N:P [50]. Various soil characteristics, such as soil texture, land-use patterns, and other properties, have different effects on the increase in microbial biomass and turnover during the process of decomposing organic matter [51]. Soil enzymatic activity has a key role to play in SOM decomposition and mineralization via several metabolic processes [34]. Notwithstanding the fact that SOM breakdown in rice crops is lowered under anaerobic circumstances, alternate wet and dry spells caused by rice–wheat rotation enhance microbial activity, which in turn speeds up SOM degradation and mineralization due to increased enzymatic activity [37,45].

Crop residues are referred to as a natural and precious resource known as "potential black gold" since they provide a considerable amount of nutrients for crop production [52]. In India, the major crops that produce leftover residues include rice, wheat, sugarcane, maize, cotton, barley, jute, soybean, rapeseed, and mustard [53]. Pearlmillet, sesame, clusterbean, and groundnut are commonly cultivated crops across the length and breadth of Rajasthan, India. The leftover material of these crops is of lingo-cellulosic in nature, non-edible to animals, and decomposes slowly. Therefore, farmers adopt the wrong practice of burning these crop wastes. Hence, composting in a scientific way for managing crop residues is the need of the hour to curtail the ill-effects of residue burning, besides the maintenance of soil organic carbon and organic matter, the major determinants of soil microbes, and nutrient cycling mechanisms. Crop residue production and utilization vary significantly throughout different regions of the country depending on the crop planted, cropping intensity, and yield [54]. About 686 million tons of crop wastes are produced in India, annually from 28 crops. Out of this total, cereals contribute the highest amount of residue followed by sugarcane (56 million tons) and others (47 million tons) [55].

The goal of the current study was to determine the effects of crop residues and inorganic fertilizer on soil microbial biomass carbon (MBC), soil microbial biomass nitrogen

(MBN), soil microbial biomass (MBP), and soil enzyme activity (soil dehydrogenases and alkaline phosphatases activity) for two years under wheat in a semi-arid environment.

2. Materials and Methods

2.1. Experimental Site

The study was carried out for a period of two years at the Agronomy Farm, Shri Karan Narendra College of Agriculture, Jobner (Rajasthan, India. Generally, the research area was in a semi- to arid environment (26°06′56″ N latitude and 75°28′29″ E longitude). Summer temperatures ranged from 26 to 48.5 °C, and winter temperatures varied from −4.5 to 32 °C. The majority of the yearly rainfall is anticipated during the monsoon season (July to September), and ranges from 400 to 660 mm on average. In the soil, the water is around 90–100 m below the surface. The soil surface, 0–15 cm, had a pH (8.05), EC (0.42 dS m^{-1}), low SOC (0.23%), and also low status of available N, P_2O_5, and K_2O (128.8, 17.90 and 154.8 kg ha^{-1}, respectively), for initial soil samples in November 2020.

2.2. Experimental Design and Treatments

In 2020–2021, the experiment was started with the wheat crop. Five partially composted crop residue treatments (control—no application of crop residue, clusterbean straw, groundnut shell, pearlmillet husk, and sesame stover with rate of 5 t ha^{-1}) and four fertilization (NPK) treatments (control—no application of fertilizers, 75% recommended dose of fertilizers, 100% RDF, and 125% RDF) were set up in a three-replication factorial randomized block design. Thus, using a random number, 20 treatment combinations were distributed at random to various plots; each plot was 3.0 m × 2.25 m in size [56]. During the second year of the experiments, every plot had the same set of treatments again. The wheat variety Raj-4238 was sown in rows 22.5 cm and seed rates 120 kg ha^{-1} on 30 November 2020–2021 and 20 November 2021–2022. To suppress weeds, hand weeding was used, and where required, plant protection measures were undertaken. The experimental crop was harvested after 4 months of sowing; the crop was harvested manually close to the ground and all harvested biomass was removed from each plot. Grain samples were air-dried on concrete, threshed, and oven-dried at 70 °C to a uniform moisture level, and then weighed.

The crop residues were decomposed for 40 days at the Vermicompost Production Unit of Sri Karan Narendra College of Agriculture, Jobner. Decomposer *Cyathus* + LA_2 (powdery form) fungi inoculant was obtained from the Division of Microbiology, IARI, New Delhi, and *Cyathus* + LA_2 inoculant was isolated from woody debris. The residue was chopped to a small size (6–7 cm); after chopping, 500 gm decomposer and 500 gm urea/100 kg crop residues were added for quicker decomposition. Water was provided to keep the water holding capacity constant (~50–60%) during the composting process. To ensure enough aeration, the composting mass was thoroughly mixed, alongside consistent decomposition and turnings (at 20 and 35 days). The weighed amount (3.375 kg/plot) of partially-composted crop residue was properly incorporated in soil up to 15 cm depth under treated plots with the help of a spade. Table 1 summarizes the chemical make-up of the crop residues employed in the experiment. According to the experimental plan, nitrogen (N), phosphorous (P), and potassium (K) were applied with urea, diammonium phosphate, and muriate of potash, respectively. Half of the N, the full dose of P, and the full dose of K were applied as a base dose at planting, and the remaining 50% of nitrogen was applied at the time of the first irrigation. The recommended dose of (100% RDF) fertilizers for the wheat crop is N-120, P_2O_5-40, and K_2O-30 kg ha^{-1}, respectively.

2.3. Soil Sampling

In both years (2020–2021 and 2021–2022), soil samples were collected (0–15 cm) at the first, second, third, and fourth months after wheat crop sowing for the determination of microbial activities by the addition of crop residues and fertilizers in soil. Samples were collected from five randomly selected spots within each plot and combined to create one composite sample from each plot. The acquired soil samples were sieved with a 2 mm wide screen to remove surface organic matter and small roots before being promptly sent to the lab for biochemical analysis. To stabilize the microbiological activity, fresh soil samples were maintained in a refrigerator (4 °C) before being analyzed within two weeks.

Table 1. Chemical composition of crop residues after 40 days of decomposition.

S. No.	Crop Residues	TC (%)		TN (%)		TP (%)		TK (%)		C:N Ratio	
		2020	2021	2020	2021	2020	2021	2020	2021	2020	2021
1.	Clusterbean straw	25.3	26.9	1.36	1.40	0.32	0.34	0.87	0.84	18.6	19.2
2.	Groundnut shell	26.6	25.3	1.04	1.10	0.27	0.26	0.83	0.79	25.6	23.0
3.	Pearlmillet husk	28.1	27.5	0.71	0.70	0.22	0.19	0.70	0.73	39.6	39.3
4.	Sesame stover	29.4	28.7	0.64	0.66	0.19	0.18	0.61	0.62	45.9	43.5

TC—total carbon, TN—total nitrogen, TP—total phosphorus, TK—total potassium and, C:N ratio—carbon nitrogen ratio.

2.4. Microbiological Analyses

Microbial biomass carbon, nitrogen, and phosphorus were estimated by fumigation-extraction [57–59]. MBC was analyzed as biomass carbon, where BC = EC/KEC and extractable carbon (EC) are calculated from treatments of carbon extracted from fumigation and non-fumigation, and KEC is the efficiency of extraction (0.45) [57]. The $CHCl_3$ fumigation approach employing K_2SO_4 extract was also used to investigate MBN. Using the Kjeldahl digestion method, the soil's nitrogen content (N) was determined [58]. The measurement of MBP was carried out as per Brookes et al. and fumigation was performed similarly to that of MBC estimation. MBP was dependent on the variation between non-fumigated and fumigated samples [59,60]. Soil dehydrogenase activity was estimated by reducing 2,3,5-triphenyltetrazolium chloride [61]. Alkaline phosphatase activity was determined using p-nitrophenyl phosphate disodium (PNPP, 0.15 M) as a substrate [62].

2.5. Statistical Analysis

Data presented in tables and figures were two-year pooled data; the results were similar for both years and pooled data provided the best representation of the observed results. Utilizing window-based statistical software, SPSS version 16.0, analysis of variance and correlation [56] were performed on the experimental data using fertilization and crop residues as factors. The data for microbial biomass, enzyme activity, and grain yield were analyzed using a Factorial Randomized Block Design (FRBD) with Duncan's Multiple Range Test at a 5% level of significance for comparing the means.

3. Results

3.1. Soil Microbial Biomass C, Microbial Biomass N, and Microbial Biomass P

Different crop residues and fertilization treatments had significantly affected the microbial biomass carbon in soil (Figure 1). The interaction between crop residues and fertilization on microbial biomass C was found to be non-significant. The MBC range in treatments with crop residues was 89.12 to 175.97 µg g^{-1}. The control treatment had the lowest MBC contents, whereas the sesame stover treatment had the highest. The MBC determined in the treatments of crop residue, in decreasing order, were as follows: sesame stover (175.97 µg g^{-1}), pearlmillet husk (172.98 µg g^{-1}), groundnut shell (164.58 µg g^{-1}), clusterbean straw (162.83 µg g^{-1}), and least in the control (135.57 µg g^{-1}) at the first month after sowing. A similar trend in the MBC content was observed at the second, third, and fourth months after the sowing of wheat. The application of 125% RDF, one of the fertilizer treatments, led to increased MBC content in the soil at the first month (181.04 µg g^{-1}) following wheat sowing, in comparison to the control (140.02 µg g^{-1}). The experiment in subsequent months, the MBC in the soil, decreased irrespective of treatments.

Different crop residues and fertilization methods significantly altered the microbial biomass nitrogen in the soil (Figure 2). The interactive effect of crop residues and fertilization on MBN was found to be non-significant. At the first month after sowing, the maximum MBN was found in the sesame stover (32.81 μg g^{-1}) and the minimum was found under control conditions (14.26 μg g^{-1}). The MBN observed in crop residue treatment in decreasing order were sesame stover, pearlmillet husk, groundnut shell, clusterbean straw, and control during the first to fourth months after sowing. Sesame stover remained at par with pearlmillet husk and groundnut shell was at par with clusterbean straw during the subsequent months following experimentation. The MBN was highest in the 125% RDF and lowest under control conditions during all the months of experimentations. In relation to MBN, a similar pattern was reported during the second, third, and fourth months after the sowing of wheat. The applications of 125% RDF and 100% RDF were found to be at par with each other.

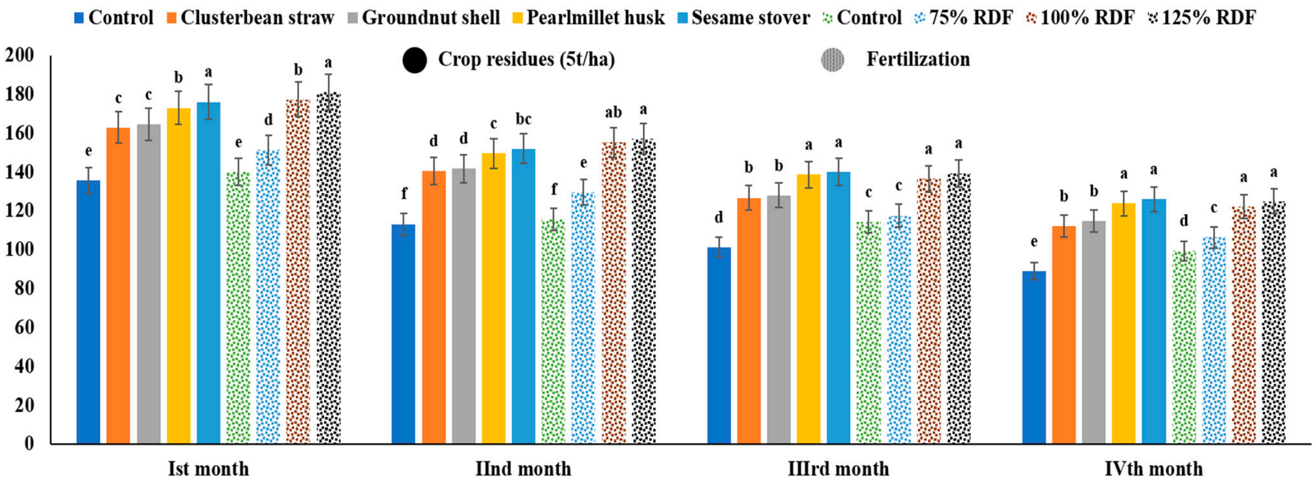

Figure 1. Effect of crop residues and fertilization on microbial biomass carbon (μg g^{-1}) at first, second, third, and fourth month after sowing. In this figure, the values followed by different lowercase letters indicate no significant difference ($p > 0.05$) by Duncan's multiple range test (DMRT).

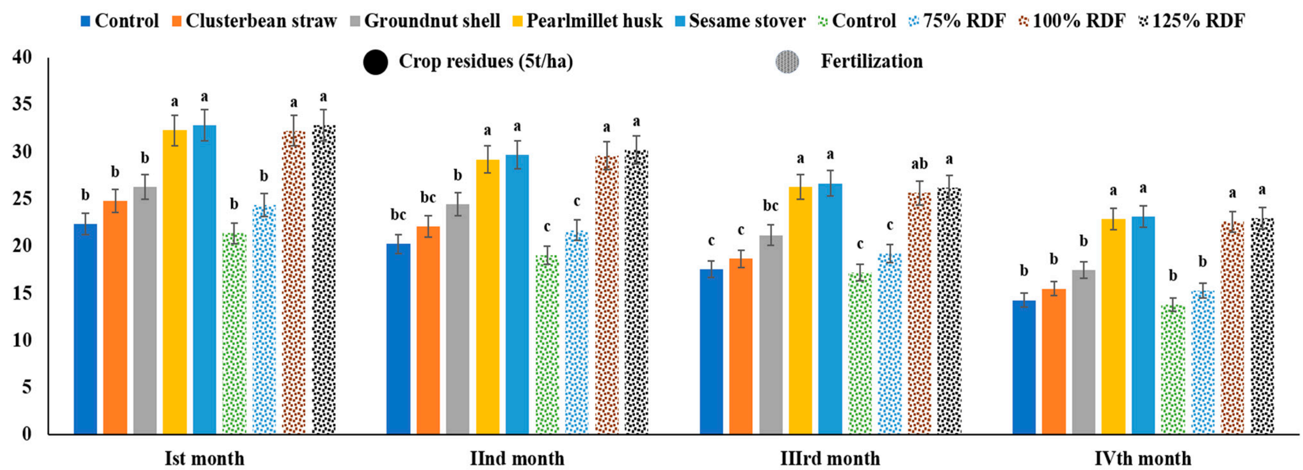

Figure 2. Effect of crop residues and fertilization on microbial biomass nitrogen (μg g^{-1}) at first, second, third, and fourth month after sowing. In this figure, the values followed by different lowercase letters indicate no significant difference ($p > 0.05$) by Duncan's multiple range test (DMRT).

Similar to MBC and MBN, various crop residues and fertilization treatments had a significant effect on the microbial biomass phosphorus in soil (Figure 3). The interaction between crop residues and fertilization on MBP was found to be non-significant. The MBP ranged from 21.91 to 8.47 μg g^{-1} during the first to fourth months after sowing. In comparison to the control, the highest MBP was recorded in sesame stover. The application of sesame stover remained at par with the application of pearlmillet husk. Among fertilization treatments, MBP ranged from 5.10 to 22.62 µg g^{-1} in the RDF and control treatment, respectively, from the first to fourth months after sowing. The application of 125% RDF and 100% RDF were found at par with each other.

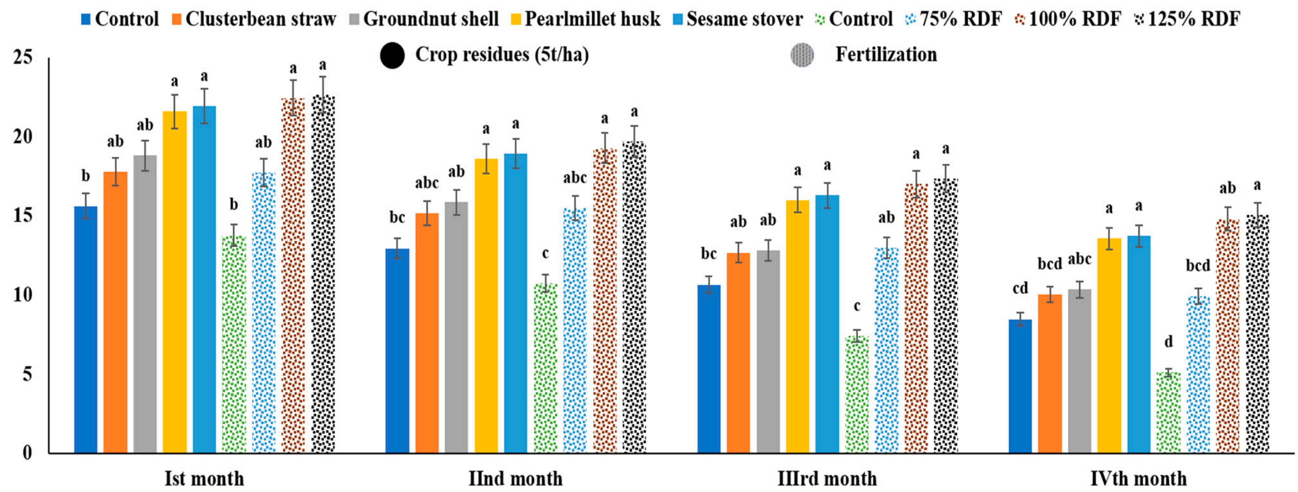

Figure 3. Effect of crop residues and fertilization on microbial biomass phosphorus (µg g^{-1}) at first, second, third, and fourth month after sowing. In this figure, the values followed by different lowercase letters indicate no significant difference ($p > 0.05$) by Duncan's multiple range test (DMRT).

3.2. Soil Enzymes

Different crop residues and fertilization treatments had considerable effects on the dehydrogenase activity accessed in soil (Table 2). The interactive effect of crop residues and fertilization on dehydrogenase activity was found to be non-significant. At the first to fourth months after sowing, the dehydrogenase activity varied from 14.26 to 19.17 g TPF kg^{-1} 24 h^{-1} in the sesame stover and in the control treatment, respectively. The sesame stover treatments showed maximum dehydrogenase activity. In the fertilization treatments, dehydrogenase activity varied between 14.12 and 19.68 µg g^{-1} soil 24 h^{-1} in the 125% RDF and control treatments, respectively, during the first to fourth months after sowing. The application of 125% RDF and 100% RDF were found to be at par with each other.

Table 2. Effect of crop residues and fertilization on dehydrogenase enzyme activity (µg TPF g^{-1} soil 24 h^{-1}) at first, second, third, and fourth month after sowing.

Treatments	First Month	Second Month	Third Month	Fourth Month
Crop residues (5 t ha^{-1})				
Control	16.3 ^{b}	15.3 ^{b}	14.5 ^{b}	14.3 ^{b}
Clusterbean straw	17.9 ^{b}	16.0 ^{b}	14.9 ^{b}	14.6 ^{b}
Groundnut shell	18.4 ^{ab}	17.5 ^{ab}	16.3 ^{ab}	16.0 ^{ab}
Pearlmillet husk	18.8 ^{a}	18.6 ^{a}	17.8 ^{a}	16.7 ^{a}
Sesame stover	19.2 ^{a}	20.0 ^{a}	18.0 ^{a}	17.0 ^{a}
Fertilization				
Control	15.7 ^{b}	15.2 ^{b}	14.5 ^{b}	14.1 ^{b}
75% RDF	17.1 ^{b}	16.8 ^{b}	15.7 ^{b}	15.1 ^{b}
100% RDF	19.2 ^{a}	18.4 ^{a}	17.3 ^{a}	16.6 ^{a}
125% RDF	19.7 ^{a}	18.7 ^{a}	17.7 ^{a}	17.0 ^{a}

RDF- Recommended dose of fertilizers. In the table, the same letters indicate no significant difference ($p > 0.05$) by Duncan's multiple range test (DMRT).

In crop residue treatments, the alkaline phosphatase activity varied from 9.12 to 13.06 µg PNP produced g^{-1} soil h^{-1} (Table 3). The activity of alkaline phosphatase was highest in the sesame stover and lowest in the control treatment. The alkaline phosphatase activities observed in crop residue treatment in decreasing order were sesame stover, pearlmillet husk, groundnut shell, clusterbean straw, and control at first month after sowing. The application of sesame stover remained at par with the pearlmillet husk. The alkaline phosphatase activity was highest (12.96 μg PNP produced g^{-1} soil h^{-1}) in the 125% RDF and lowest (9.35 μg PNP produced g^{-1} soil h^{-1}) under control conditions during all the months of experimentations. The application of 125% RDF remained at par with the 100% RDF. The interaction between crop residues and fertilization on MBP was found to be non-significant.

Table 3. Effect of crop residues and fertilization on alkaline phosphatase enzyme activity (μg PNP produced g^{-1} soil h^{-1}) at first, second, third, and fourth month after sowing.

Treatments	First Month	Second Month	Third Month	Fourth Month
Crop residues (5 t ha^{-1})				
Control	10.2 ^{b}	10.21 ^{b}	9.3 ^{b}	9.12 ^{b}
Clusterbean straw	10.5 ^{b}	10.3 ^{b}	10.0 ^{b}	9.7 ^{b}
Groundnut shell	11.6 ^{ab}	11.5 ^{ab}	11.2 ^{ab}	10.8 ^{ab}
Pearlmillet husk	12.9 ^{a}	12.9 ^{a}	12.4 ^{a}	12.3 ^{a}
Sesame stover	13.1 ^{a}	13.0 ^{a}	12.6 ^{a}	12.5 ^{a}
Fertilization				
Control	10.01 ^{b}	9.8 ^{b}	9.5 ^{b}	9.4 ^{b}
75% RDF	11.0 ^{ab}	10.9 ^{b}	10.5 ^{b}	10.6 ^{ab}
100% RDF	12.7 ^{a}	12.6 ^{a}	12.1 ^{a}	11.8 ^{a}
125% RDF	13.0 ^{a}	12.8 ^{a}	12.3 ^{a}	12.0 ^{a}

RDF—Recommended dose of fertilizers. In the table, the same letters indicate no significant difference ($p > 0.05$) by Duncan's multiple range test (DMRT).

3.3. Correlation Coefficient between Soil Biological Properties and Grain Yield

Soil MBC, MBN, and MBP were positively and significantly correlated to the soil dehydrogenase activity and alkaline phosphatase activity of the soil (Table 4). There was a significant positive correlation between microbial biomass C and alkaline phosphatase enzyme activity (r = 0.925 **) and dehydrogenase enzyme activity (r = 0.938 **). Grain yield was positively and significantly correlated with MBC (r = 0.765 *), MBN (r = 0.679 *), MBP (r = 0.666 *), DHA (r = 0.669 *), and APA (r = 0.661 *).

Table 4. Correlation coefficient between soil biological properties and grain yield.

	MBC	MBN	MBP	DHA	APA	Grain Yield
MBC	1.000	0.921 **	0.955 **	0.950 **	0.918 **	0.765 *
MBN		1.000	0.976 **	0.959 **	0.984 **	0.679 *
MBP			1.000	0.980 **	0.966 **	0.666 *
DHA				1.000	0.972 **	0.669 *
APA					1.000	0.661 *
Grain yield						1.000

MBC: Microbial biomass carbon, MBN: Microbial biomass nitrogen, MBP: Microbial biomass phosphorous, DHA: dehydrogenase, APA: Alkaline phosphatase, * Correlation is significant at the 0.05 level ** Correlation is significant at the 0.01 level.

3.4. Grain Yield

Figures 4 and 5 indicated the interactive effect of crop residues and fertilization on grain and straw yield of wheat. The maximum grain and straw yield of wheat (5450 and 9097 kg ha^{-1}) were recorded with 125% RDF + clusterbean straw and minimum under control (2260 and 7041 kg ha^{-1}). The application of 100% RDF + clusterbean straw was observed to be statistically at par with the application of 125% RDF + clusterbean straw. The maximum grain and straw yield (Figure 6) were recorded in clusterbean straw treatment

(4897 and 7256 kg ha^{-1}) and were lowest under control treatments (3681 and 5277 kg ha^{-1}). The application of clusterbean straw treatments remained statistically at par with the groundnut shell treatments. When compared to the control (3513 and 5209 kg ha^{-1}), the application of 125% RDF was registered in the maximum grain and straw yields (4902 and 7272 kg ha^{-1}).

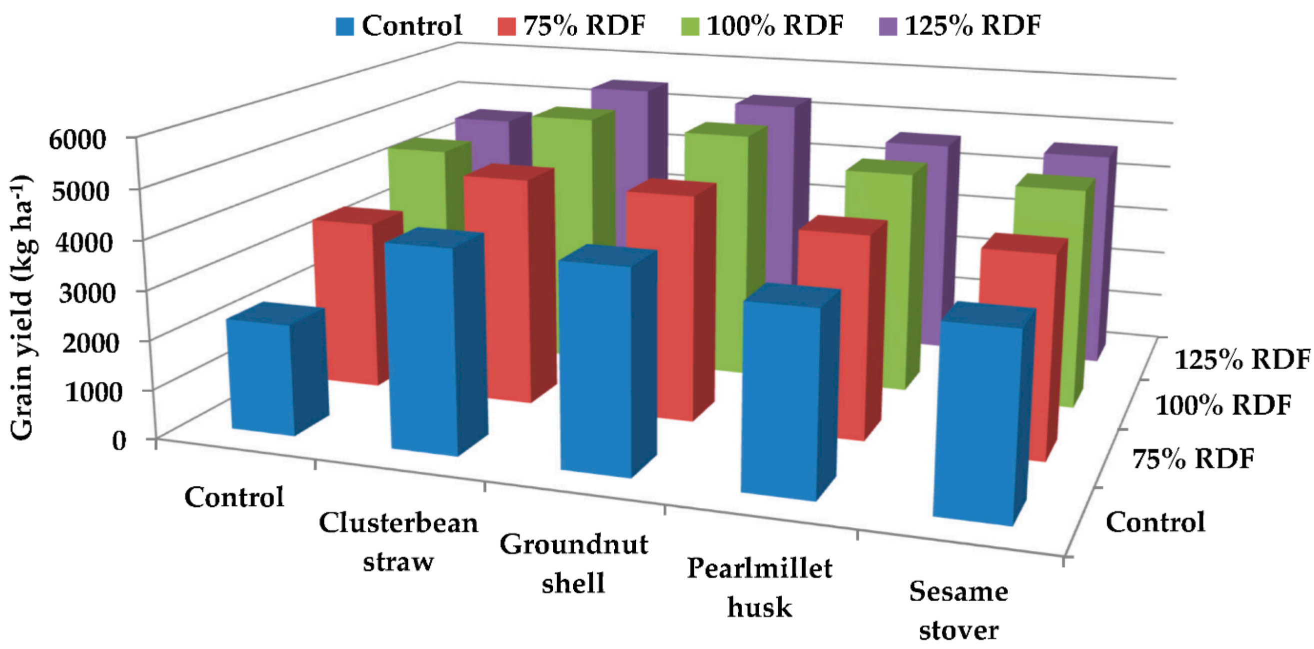

Figure 4. Interaction effect of crop residues and fertilization on grain yield of wheat.

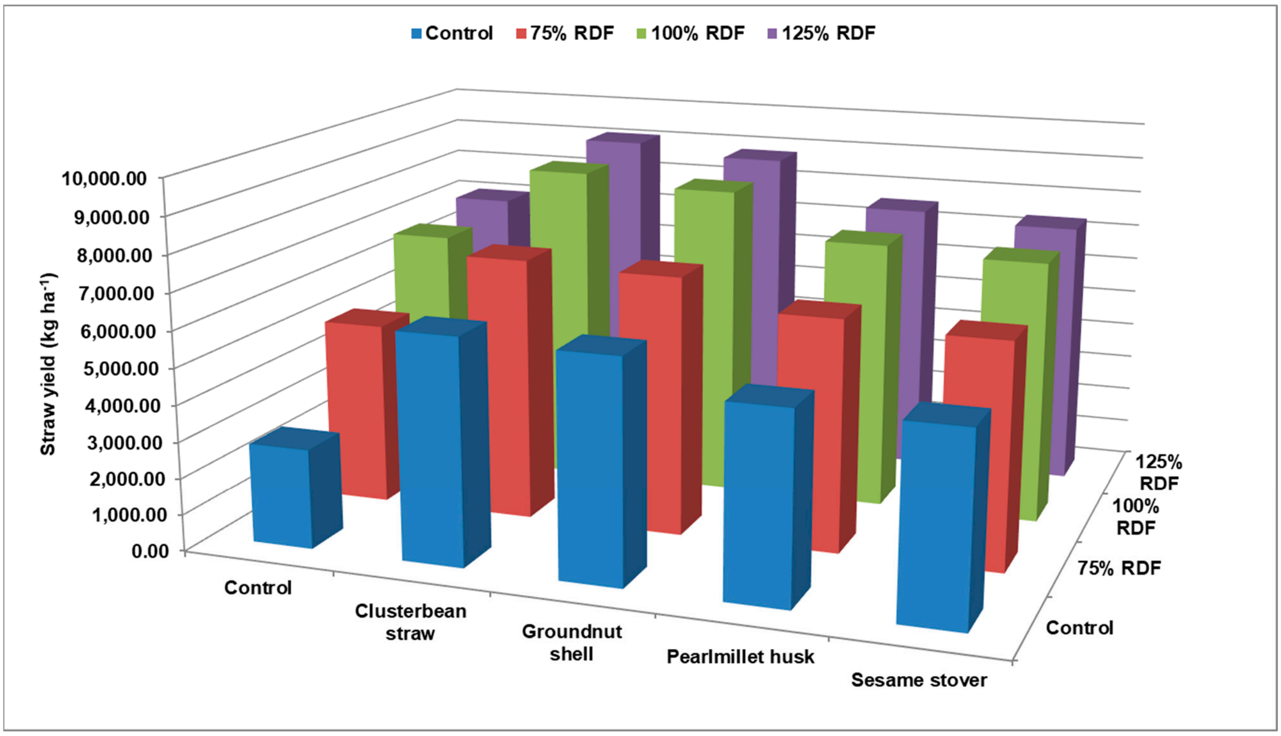

Figure 5. Interaction effect of crop residues and fertilization on straw yield of wheat.

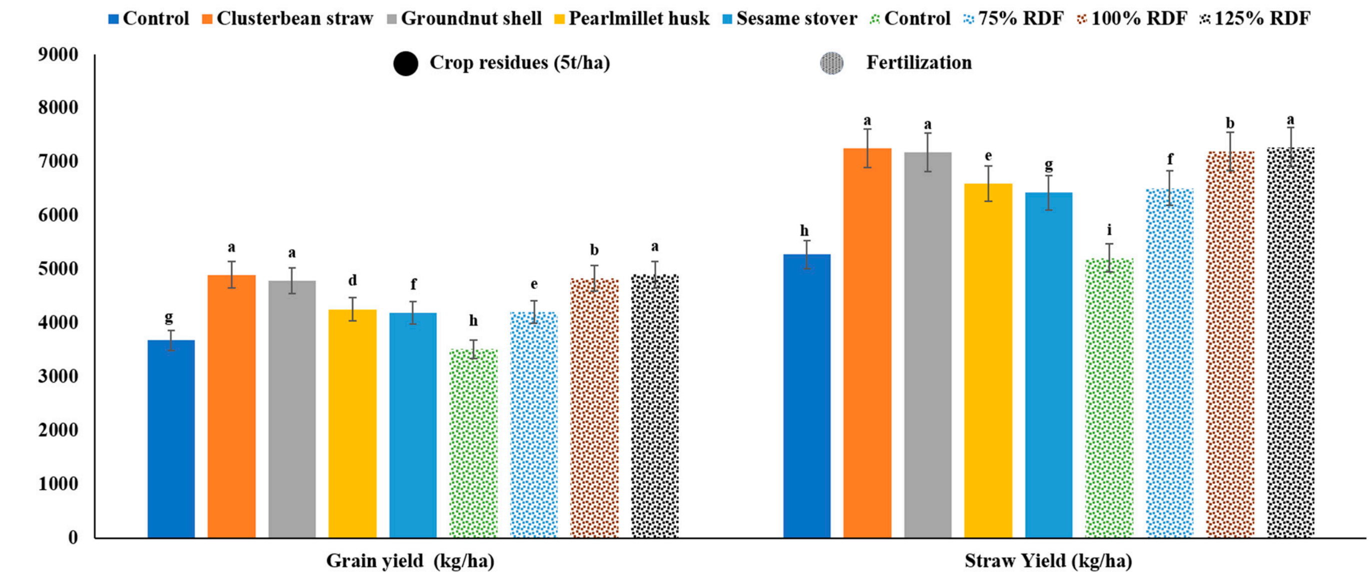

Figure 6. Effect of crop residues and fertilization on wheat yields (kg ha^{-1}) (grain and straw). In this figure, the values followed by different lowercase letters indicate no significant difference ($p > 0.05$) by Duncan's multiple range test (DMRT).

4. Discussion

4.1. Soil Microbial Biomass

The microbial biomass denotes the living component of soil organic matter but excludes micro-fauna and plant roots. The soil microbial biomass, which represents about 1–5% of total soil organic carbon, can provide an effective early warning of the improvement or deterioration of soil quality as a result of different management practices [5,63]. Our study found that the microbial biomass C, N, and P were increased significantly due to the addition of crop residues and inorganic fertilizers. When a carbon substrate was added, enzyme activity and microbial growth were usually enhanced, and they often reduced when the carbon supply was depleted [9,12,64]. The readily metabolizable carbon and nitrogen in sesame stover and pearlmillet husk are the most influential factors contributing to the biomass increase, in addition to increasing root biomass and root exudates due to greater crop growth. Sesame stover and pearlmillet husk also have higher C/N ratio than other crop residues, which results in a considerably increased content of MBC, MBN, and MBP, and decreased crop growth at later phases under similar treatments. Energy for the microbial population is provided by the availability of carbonaceous materials and substrates to the soil from the degradation of organic substances and roots beneath [37,65–69]; all of them noted the same results that the application of crop residues increased MBC, MBN, and MBP. Soil organic carbon pools that act as a substrate for enzymes and are used by microorganisms, and whose activity increases by the addition of an inorganic nutrient source, may be the cause of the significant proliferation of MBC, MBN, and MBP, caused by the application of fertilizers (NPK) [12,37,70,71]. The application of 125% RDF recorded maximum contents of MBC, MBN, and MBP. Increased levels of fertilizers may have increased root biomass and exudates, which in turn may have given soil microbes more carbon and energy over time, but a lack of organic substrate during the harvesting stage could result in a sharp decline in microbial biomass [39,45,72–75]. The significant positive correlation of microbial biomass C, N, and P with dehydrogenase and alkaline phosphatase enzyme activity might be due to the application of crop residues which support the development of microbial biomass during the entire growing period of the crop. While decomposition processes in soil proceed, microbial activity gradually decreases as the more resistant structure and bio products of microbial activity accumulate [12,37,63–65].

4.2. Soil Enzymes Activity

Enzyme activities are an important index of the biological activity of a soil because they are involved in the dynamics of soil nutrient cycling and energy transfer [24,34]. Enzymatic processes are closely associated with soil fertility as they mediate the conversion of unavailable forms of nutrients to forms that are readily assailable by plants and microbes [34,37]. Since dehydrogenase activity is only present in viable cells, it is thought to reflect the total range of oxidative activity of soil micro flora and consequently may be considered to be a good indicator of microbial activity [12,34,76]. The phosphatases are a broad group of enzymes that hydrolyze esters and anhydrides of phosphoric acid. Phosphatases are important because they provide P for plant uptake by releasing PO_4 from immobile organic P. In the present study, different crop residues and fertilizer treatments greatly affected dehydrogenase and alkaline phosphatase activity. The application of sesame stover and 125% RDF recorded higher enzyme activity. The quantity of humic substances increases adsorption sites for enzymes. As a result, there are more adsorbed enzymes [5,77,78]. Soil enzyme activity was increased by the level of organic matter and the inclusion of organic material present in the soil [5,77,78]. Typically, the increase in microbial biomass caused by the addition of organic matter to the soil has been employed to interpret this increased activity [37,45,79]. A rise in soil humus content protects the enzyme fraction, which may possibly account for the increase in activity [12,34,80]. The studies are consistent with the observation that mineral nitrogen fertilization has little effect on dehydrogenase activity [5,45,76]. Alkaline phosphatase activity was limited in control and improved in the treatments with NPK fertilizer. Other researchers [12,34,37,78–80] who discovered a rise in alkaline phosphatase activity under organic and inorganic fertilization also observed similar outcomes.

4.3. Grain Yield

The application of various crop residues and fertilization treatments had a substantial impact on wheat grain production. The maximum grain yield was recorded with the application of clusterbean straw and 125% RDF. Clusterbean straw's consistent release of nutrients throughout the course of a plant's growth and development kept the synthesis of metabolites and photosynthetic efficiency at a greater level. The continuous availability of nitrogen, phosphorus, and potassium in plants at all critical stages, which might have resulted in higher photosynthesis, better root development, and which increased the higher supply of photosynthates from source to sink [81,82] led to better wheat grain and straw yields. Crop yields might be directly increased by properly managing crop leftovers, which would also increase nutrient availability, enhance soil structure, increasing WHC and also reducing erosion [83–86].

5. Conclusions

It can be inferred from the two years of investigation that the plant residues of previous crops should be partially decomposed during the intermittent time from the previous crop's harvest to next crop's sowing, and should be applied before the sowing of the next crop to obtain a sustained higher yield by maintaining the biological characteristics of soils. The application of fertilizers should be practiced to harvest higher crop yield by maintaining soil nutrient balance. The continuous application of crop residues and fertilization had a significant impact on MBC, MBN, MBP, and soil enzymatic activities in the present investigation. The sesame stover and 125% RDF (NPK-150:50:37.5 kg ha^{-1}) treatments had the highest microbial biomass and enzyme activity. According to the study's findings, farmers should be advised of the value of reintroducing crop residues to the soil. They will be able to use the land more effectively, reduce the cost of production inputs, and boost the agricultural economy. These findings imply that crop leftovers are crucial for managing soil quality successfully.

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