

# Influence of Vermicompost as the Source of Nitrogen in Various Combinations with Chemical Fertiliser on Winter Wheat Productivity

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There is rarely any study that deals with the application of vermicompost in combination with chemical fertiliser to study the growth and yield variables of wheat crop in the typical agro-climatic conditions of saline sandy agricultural land of tropical semi-arid climatic condition with vast fluctuations of temperature between summer and winter seasons. Hence, the current study has been planned with a broader objective of utilising the organic resources by preparing vermicompost and applying it as the partial substitute of chemical fertiliser to cultivate wheat in an eco-friendly manner in saline sandy agricultural land of the tropical semi-arid zone. For achieving the intended goal, an experiment was conducted in the field of 'Soil-Water-Plant Laboratory', Department of Civil Engineering, IIT Ropar, Punjab, India during the winter season (*rabi*) of 2018-19. In this experiment, Randomized Block Design (RBD) was followed, and four treatments were used, including T1: 100% RD using chemical fertilisers, T2: 50% RD using chemical fertilisers + 50% of nitrogen through vermicompost, T3: 75% RD using chemical fertilisers + 25% of nitrogen through vermicompost and T4: control (without any additional nutrients). Each treatment was replicated nine times. Plot size was 4m × 6m, and row to row spacing was 0.2 m. Following statistical analysis, it was found that treatment T2 (50% RD using chemical fertilisers + 50% of nitrogen through vermicompost) showed the best results, which were reflected in different parameters such as number of effective tillers per plant, ear length, number of grains per ear, and test weight, grain yield and straw yield of the wheat crop in comparison to other treatments. In this case, an almost equal amount of nitrogen supply from both organic and inorganic sources is responsible for getting the best results.

**Keywords:** nutrient management; agriculture; soil fertility; crop yield

## I. INTRODUCTION

Wheat (*Triticum aestivum* L.) has the highest importance among cereal crops, and it is widely cultivated as a food grain. From ancient times, wheat has been playing a significant role in the economy of several countries. Among different cereal foods, this crop has 30% contribution, and in the aspect of total food calories, it supplies almost 20% calories directly or indirectly in the human body (Lal, 2007). Thus, necessary measures are required to increase its production to ensure a sufficient food supply. Many factors control wheat productivity; among them, mineral nutrition,

especially nitrogen, plays a significant role. According to Palaniappan and Annadurai (2018), chemical fertilisers supply nutrients to the crop easily within a short period. Although the crop plants quickly utilise some parts of their elemental constituents, the remaining parts are either lost or unavailable to the plants resulting in passing through different chemical or biochemical reactions in the soil. Injudicious use of chemical fertilisers leads to environmental pollution and health problems (Savci, 2012). Hence, nutrient management is a vital stage in crop production. Organic manures can promote nutrients supply to the plant, improve its productivity, and maintain soil

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health (Zaller & Kopke, 2004; Nouraein *et al.*, 2020). According to Suthar (2008), among different manures, vermicompost provides a crucial source of different nutrients when it is applied in appropriate ratios with mineral fertilisers. Aira *et al.* (2002) reported that earthworms and microorganisms jointly convert organic materials into manure in the vermicomposting process. Bajsa *et al.* (2004) reported that vermicomposting is an easy and efficient compost preparation technique that can maintain a higher nutrient status in composted materials. Many scientists have worked on organic and inorganic fertiliser and their applications in agriculture. Chaudhry *et al.* (2017) has evaluated the effects of the recommended dose of fertiliser (RDF), vermicompost, *Azotobacter*, and phosphate-solubilising bacteria (PSB). In the 2-year study, they have found that the treatments with RDF combined with vermicompost at 5 t. ha<sup>-1</sup> mixed with *Azotobacter* and PSB has increased the grain yield by 21.5%, while a combination of RDF and compost at 10 t. ha<sup>-1</sup> mixed with *Azotobacter* and PSB has an increment of 20.1 %, over the yield by the RDF treatment alone. From their study, Devi *et al.* (2011) reported that the application of 100% RDF (i.e., 120: 26.4: 50 N: P: K kg. ha<sup>-1</sup>) combined with the mixture of vermicompost at 1 t. ha<sup>-1</sup> and phosphate solubilising bacteria (PSB) and another combination of 75% RDF with vermicompost at 1 t. ha<sup>-1</sup> mixed with PSB showed higher yield components and yield of wheat compared to the other treatments. Hu *et al.* (2016) arranged an experiment on the wheat crop with six treatments, such as fertilisation with nitrogen (N), phosphorus (P), manure (M), NP, NPM, and control (without fertilisation). From their experiment, they showed that the grain yield, fertiliser-contribution rate (FCR), and precipitation-use efficiency (PUE) with manure (M) increased annually at the rate of 89 kg. ha<sup>-1</sup>. y<sup>-1</sup>, 1.47 kg. kg<sup>-1</sup>. y<sup>-1</sup>, and 0.13 kg. mm<sup>-1</sup>. y<sup>-1</sup>, respectively. In their field experiments, Laxminarayana *et al.* (2011) reported that combined use of nitrogen, phosphorus, and potassium and farmyard manure showed a higher yield (18.7 Mg. ha<sup>-1</sup>) of sweet potato significantly. They also revealed that the combined use of organic manures and balanced fertilisers and lime produces higher crop yields and increased soil fertility strength. Ali *et al.* (2020) arranged a 2-years experiment on bread wheat. They showed that

vermicompost application resulted in the highest productivity among three organic manures (press mud, vermicompost, and farmyard manure). In their experiment, Chopra *et al.* (2016) remarked that among 27 treatments (consisted of organic manures, inorganic fertilisers and biofertilisers), the treatment consisted of poultry manure at 5 t. ha<sup>-1</sup> combined with 75% NPK mixed with dual inoculation of *Azotobacter* and PSB showed a significantly high yield of the wheat crop. Hafez *et al.* (2020) conducted an experiment on wheat crops and noticed that the highest grain yield and nutrient uptake were performed at 75% field capacity from the combined application of vermicompost and biochar.

Following the literature review, it is observed that some studies (Devi *et al.*, 2011; Hu *et al.*, 2016; Chopra *et al.*, 2016; Chaudhry *et al.*, 2017; Singh *et al.*, 2018; Hafez *et al.*, 2020) were conducted to explore the winter wheat yield under the combinational treatment effects of vermicompost, chemical fertiliser and/or other supplements. It is well known that vermicompost provides a crucial source of different nutrients. Literature also indicates that vermicompost is beneficial in decreasing soil salinity and sodicity and consequently leads to increased wheat production by enhancing soil quality (Hafez *et al.*, 2020; Ding *et al.*, 2021). Interestingly, rarely any study deals with vermicompost application in combination with chemical fertiliser to study the growth and yield variables of wheat crop in the typical agro-climatic conditions of saline sandy agricultural land of tropical semi-arid climatic condition with huge fluctuations of temperature between summer and winter seasons. Hence, the current study has been planned with a broader objective of utilising the organic resources by preparing vermicompost and applying it as the partial substitute of chemical fertiliser to cultivate wheat in an eco-friendly manner in saline sandy agricultural land of the tropical semi-arid zone. It also aimed to determine the optimum nutrient mixture.

## II. MATERIALS AND METHOD

The experiment was carried out at the field of soil -water - plant laboratory, Dept. of Civil Engineering, IIT Ropar, Punjab (latitude 30° 57' 52.17" N, longitude 76° 28' 50.12" E), India during the winter season (*rabi*) of 2018-19. The

soil of the experimental field was sandy silt in texture, having BD 1.56 g. cc<sup>-1</sup>, pH 8.5, organic carbon 0.79%, available nitrogen 251 kg. ha<sup>-1</sup>, available phosphorus 19 kg. ha<sup>-1</sup> and available potassium 267 kg. ha<sup>-1</sup>. Bulk density was measured by the method of Blake and Hartge (1986). Soil pH was determined with the help of Backman's pH meter. Soil organic carbon, available nitrogen, available phosphorus, and available potassium were estimated by Walkley and Black's rapid titration method, Kjeldahl method, Olsen's method, and Flame photometer method, respectively (Jackson, 1973).

The experimental site was a tropical semi-arid type and average rainfall ranging from 500 mm to 750 mm. Considerable variations are observed in maximum and minimum temperatures during summer (about 46 °C) and winter season (about 4 °C). Wheat variety PBW343 was chosen as a *rabi* crop, and it was sowed on the 3<sup>rd</sup> week of November 2018. Randomized Block Design (RBD) was followed by 4 different nutritional treatments in this experiment, and each treatment was replicated nine times. Treatments were T1: 100% RD using chemical fertilisers ( i.e. N- 120 Kg. ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub>- 60 Kg. ha<sup>-1</sup>, K<sub>2</sub>O- 40 Kg. ha<sup>-1</sup>), T2: 50% RD using chemical fertilisers (i.e. N- 60 Kg. ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub>- 30 Kg. ha<sup>-1</sup>, K<sub>2</sub>O- 20 Kg. ha<sup>-1</sup>) blended with 50% of nitrogen through vermicompost, T3:75% RD using chemical fertilisers (i.e. N- 90 Kg. ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub>- 45 Kg. ha<sup>-1</sup>, K<sub>2</sub>O- 30 Kg. ha<sup>-1</sup>) mixed with 25% of nitrogen through vermicompost and T4: control (without any additional nutrients). Plot size was 4 m × 6 m, row to row spacing was 0.2 m, and plant to plant spacing was 0.1 m. For this experiment, vermicompost was prepared in a tank (Palaniappan and Annadurai, 2018) and used for various treatments. Organic carbon (11.8%), total nitrogen (1.22%), total P<sub>2</sub>O<sub>5</sub> (2.07%), and total K<sub>2</sub>O (0.79%) had been predetermined were present in applied vermicompost.

In crop study, growth parameters (plant height, dry matter accumulation, leaf area index), yield attributes (number of effective tillers plant<sup>-1</sup>, ear length, number of grains ear<sup>-1</sup>, and test weight), and yield (grain yield and straw yield) were recorded at the time of harvest. Statistical analysis of the collected data was performed using SPSS V.25.0 (IBM, USA) software to establish the most suitable treatment. Moreover, the Pearson correlation coefficients were calculated for a few

variables (number of effective tillers per plant, LAI, ear length, grain per ear, grain yield, and straw yield) to evaluate the degree of association between two selected variables for each treatment.

### III. RESULT AND DISCUSSION

Different doses of fertiliser and organic manure (vermicompost) remarkably influenced the growth, yield attributes, and yield of the wheat crop in this present research. Figure 1 and Figure 2 show the descriptive statistics of all variables. For checking the applicability of parametric statistical tests, various assumptions were checked for the data set using the IBM SPSS software.

These included (1) test of normality - using the Shapiro-Wilk method (2) test of homogeneity of variances, and (3) test for non-multicollinearity using Spearman correlation coefficient.

These test results were found to be good enough to proceed with a parametric test like ANOVA. Results of one-way ANOVA results (Table-1) showed that there were significant differences among the nutritional treatments (T1, T2, T3, and T4) in the case of all variables except the Leaf Area Index (LAI). To understand the impact of different treatments on each variable, a Post-hoc test using Bonferroni multiple comparisons (Table 2) was conducted.

Table 1. Results of one-way ANOVA to study the difference in the measure of variables across the nutritional treatments

Sl. No.	Variables	F value
1	Plant height [10 <sup>-2</sup> m]	27.51*
2	DMA [10 <sup>-3</sup> kg/m row length]	29.26*
3	Leaf area index	1.87
4	No. of effective tillers per plant	19.79*
5	Ear length [10 <sup>-2</sup> m]	7.97*
6	Grain per ear	57.4*
7	Test weight [10 <sup>-3</sup> kg]	36.17*
8	Grain yield [kg/10 <sup>2</sup> m <sup>2</sup> ]	90.24*
9	Straw yield [kg/10 <sup>2</sup> m <sup>2</sup> ]	105.62*
10	Harvest Index [%]	8.21*

\*Significant at the  $p \leq 0.05$  level

In Figure 1, treatment T3 has indicated maximum plant height followed by treatments T1 and T2, whereas T4 showed minimum plant height. Results of the post-hoc test (Table 2) indicated that the mean difference of plant height in T3 was significantly ( $p \leq 0.05$ ) higher in comparison to other treatments (T1, T2, and T4). According to Borse *et al.* (2019), plant height is influenced by the combined application of chemical fertiliser and organic manure. This combination increases the size of a plant cell. As a result, the leaf area and photosynthesis rate rise. These ultimately

make the plant taller. It was also observed that dry matter accumulation was highest in treatment T3, followed by treatments T1 and T2. Treatment T4 showed the lowest value in dry matter accumulation, as there were no chemical/ organic fertilisers. The result of the post-hoc test revealed that the mean difference of dry matter accumulation was significantly ( $p \leq 0.05$ ) higher in the case of T3 in comparison to all other treatments, but the mean difference was not significant ( $p > 0.05$ ) between T2 and T1 (Table 2).

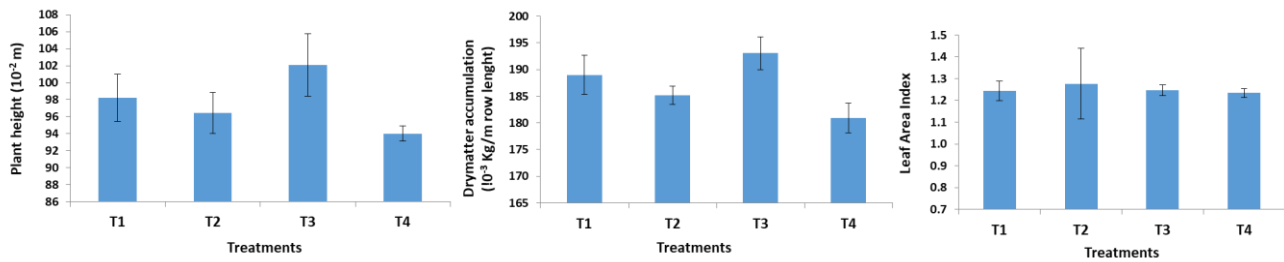


Figure 1. Comparisons of growth-related variables under different treatments

Table 2. Comparison between two different nutritional treatments for each of the variables under study

Treatments	Mean Difference									
	Plant height [10 <sup>-2</sup> m]	DMA [10 <sup>-3</sup> kg/m row length]	Leaf area index	No. of effective tillers per plant	Ear length [10 <sup>-2</sup> m]	Grain per ear	Test weight [10 <sup>-3</sup> kg]	Grain yield [kg/ 10 <sup>2</sup> m <sup>2</sup> ]	Straw yield [kg/ 10 <sup>2</sup> m <sup>2</sup> ]	Harvest Index [%]
T4/T1	-4.02*	-8.08*	-0.16	-0.88*	-0.24	-0.45	-1.18	-4.17*	-3.01*	-1.64*
T4/T2	-1.41	-4.32*	-0.29	-1.23*	-1.46*	-5.26*	-8.49*	-9.60*	-13.99*	-0.93
T4/T3	-9.22*	-12.16*	-0.15	-0.43	-1.06*	-3.46*	-5.17*	-5.33*	-11.37*	0.69
T1/T2	2.61	3.77	-0.13	-0.35	-1.22*	-4.82*	-7.32*	-5.43*	-10.99*	0.71
T1/T3	-5.20*	-4.07*	0.01	0.44	-0.82	-3.01*	-3.99*	-1.16	-8.36*	2.33*
T2/T3	-7.81*	-7.84*	0.14	.79*	0.40	1.81*	3.33*	4.27*	2.63*	1.62*

\* The mean difference is significant at the  $p < 0.05$  level

The high accumulation of dry matter in T3 followed by T1 could be due to the high growth of plants with higher levels of major nutrients, which resulted from the adequate food supply (Yesuf & Balcha, 2014) due to the higher amount of chemical fertilisers (75% and 100% of RDF in the case of T3 and T1, respectively). In the case of LAI, treatment T2 showed maximum value, followed by treatments T1, T3, and T4. The mean difference was not significant ( $p > 0.05$ ) among all treatments (Table 2). These results are in accordance with those observed by Diallo *et al.* (2019) and Yesuf and Balcha (2014). They noticed that the high rate of photosynthesis increased in plant dry matter, but it was not dependent on the fertiliser application.

In the case of effective tiller counting, treatment T2 showed the highest number of tillers per plant, followed by treatments T1 and T3. The lowest number of tillers was observed in the case of treatment T4 (Figure 2). Although the mean difference for the number of tillers per plant was not significant ( $p > 0.05$ ) between T2 and T1, significant ( $p \leq 0.05$ ) mean differences were observed for T2 vs. T4 and T2 vs. T3 (Table 2). The proper nitrogen application resulted in the reduction of mortality of tillers and produced more tillers (Yesuf & Balcha, 2014). Production of fertile tillers results in higher yield because the number of effective tillers is important in yield. According to Hu *et al.* (2016), they also reported that the use of a combined form of organic manure and chemical fertilisers improves soil quality. Thus, it can be postulated that the use of vermicompost mixed with chemical fertilisers played a role in generating more tillers per plant in the case of T2 and T3. The highest ear length was observed in treatment T2, followed by treatments T3 and T1. The lowest ear length was seen in treatment T4. From the result of the post-hoc test, it was found that the mean difference of ear length was significant ( $p \leq 0.05$ ) for T2 vs. T1 and T2 vs. T4, but the mean difference was insignificant ( $p > 0.05$ ) between T2 and T3 (Table 2). This might be due to the positive impact of organic manure (vermicompost) on the supply of nutrients in the case of combinational application of chemical fertilisers and organic manure. These results are in agreement with the finding of Borse *et al.* (2019).

The value of grain per ear was maximum in treatment T2, followed by treatments T3 and T1 (Figure 2). The minimum value was observed for treatment T4. Table 2. depicted that the mean difference of grain per ear in T2 was significantly ( $p \leq 0.05$ ) higher than other treatments (T1, T3, and T4). According to Chopra *et al.* (2016), nitrogen promotes the initiation of spikelets that resulted in more seeds per spike, but more nitrogen levels decreased the number of seeds due to increased vegetative growth. Nitrogen applied in optimum dose decrease the chance of seeds to deteriorate (Seiling *et al.*, 2005). In this study, vermicompost as a source of nitrogen played a crucial role in producing more grain in each ear, as observed in the case of T3 and T2. Test weight was highest for treatment T2, followed by treatments T3, T1, and T4. The mean difference of test weight was significant ( $p \leq 0.05$ ) between the two treatments except for T1 vs. T4 (Table 2). These results indicated the combined use of chemical fertilisers and vermicompost plays a crucial role in the maturity of grain.

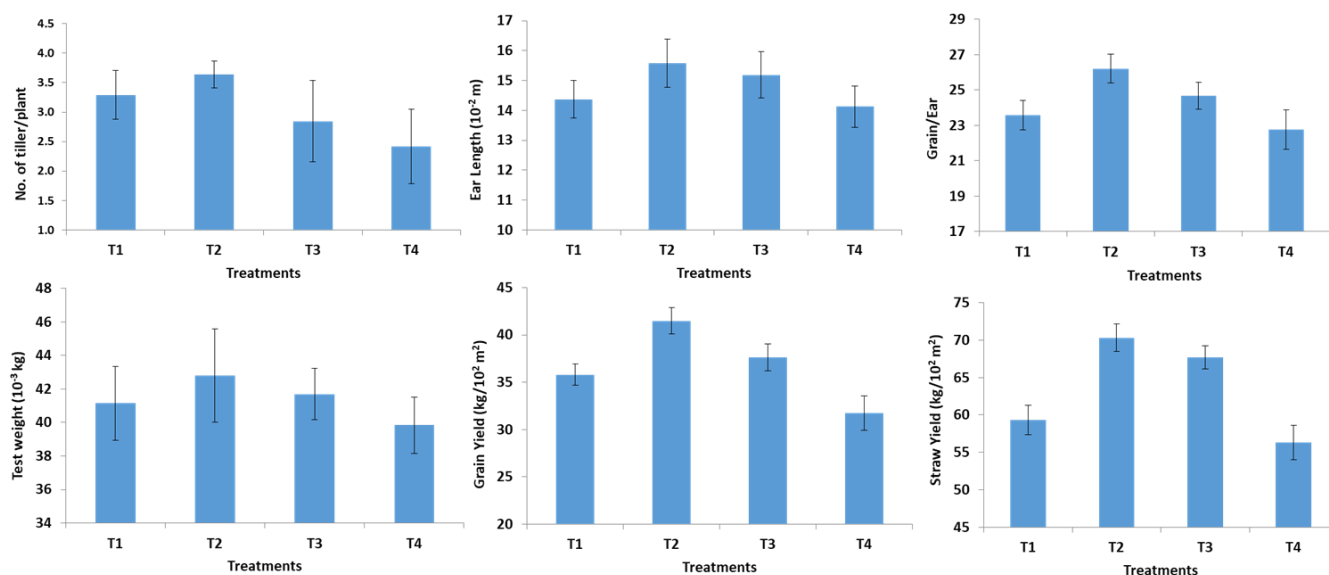


Figure 2. Comparisons of yield related variables under different treatments

Grain yield is the final reflection of all nutritional treatments through various developmental stages of the crop. The results of post-hoc test have shown that the maximum grain yield was obtained from treatment T2, followed by the treatments T3, T1, and lastly, T4. The mean difference of grain yield in T2 was significantly ( $p \leq 0.05$ ) higher in comparison to other treatments (T1, T3, and T4), and there was significantly ( $p \leq 0.05$ ) higher mean the difference among all treatments except T1 vs. T3 (Table 2). The highest straw yield was found by treatment T2, followed by the treatments T1, T3, and T4, in that order. Lastly, the mean difference between each pair of treatments was significant ( $p \leq 0.05$ ). According to Suhane *et al.* (2008) and Ansari (2011), vermicompost is rich in nutrients, which increases crop yield. The result of the current research is in agreement with Karmegam and Daniel's (2000) findings. They mentioned that vermicompost has a vital role in improving the growth and yield of different crops. The present result is also supported by the findings of Patil and Sheelavantar (2000) and Palaniappan and Annadurai (2018). In their study, the application of vermicompost improved crop yield and quality. This might be due to the easy accessibility of nutrients and soil environment for better retention of nutrients and water due to organic manures and, finally, the effect on grain yield. The highest harvest index (%) was observed in treatment T1 (HI=37.84) followed by treatments T2 (HI=37.14), T4 (HI=36.20), and T3 (HI=35.52), but

there was no significant ( $p > 0.05$ ) difference in T4 vs. T2, T4 vs. T3, and T2 vs. T1. Harvest index is directly related to the biological yield and grain yield, which ultimately depends upon the accessibility of nutrients, especially nitrogen. As the harvest index is the ratio of grain yield and biological yield (grain + straw yield), no clear trend can be perceived for various treatments. The treatment, which increased grain yield, also increased straw yield, and thus, the overall value of harvest index remained inconclusive.

Table 3. Correlation between variables under different nutritional treatments (T1, T2, T3, and T4)

		No. of effective tillers per plant	Leaf area index	Ear length [10 <sup>-2</sup> m]	Grain per ear	Grain yield [kg/ 10 <sup>2</sup> m <sup>2</sup> ]	Straw yield [kg/ 10 <sup>2</sup> m <sup>2</sup> ]
<b>No. of effective tillers per plant</b>	<b>T1</b>	1	-.795*	-.150	-.059	-.479	.387
	<b>T2</b>	1	.225	-.415	-.058	-.344	.286
	<b>T3</b>	1	-.263	-.215	-.072	-.163	.357
	<b>T4</b>	1	.365	.054	-.081	-.286	-.543
<b>Leaf area index</b>	<b>T1</b>	-.795*	1	.207	.161	.081	-.539
	<b>T2</b>	.225	1	-.020	-.304	.278	.162
	<b>T3</b>	-.263	1	.065	-.076	.514	-.142
	<b>T4</b>	.365	1	.145	-.680*	.142	-.552
<b>Ear length [10<sup>-2</sup> m]</b>	<b>T1</b>	-.150	.207	1	.349	-.381	-.157
	<b>T2</b>	-.415	-.020	1	.044	.309	-.542
	<b>T3</b>	-.215	.065	1	.124	-.395	-.236
	<b>T4</b>	.054	.145	1	-.187	.345	-.100
<b>Grain per ear</b>	<b>T1</b>	-.059	.161	.349	1	-.575	.495
	<b>T2</b>	-.058	-.304	.044	1	-.206	-.406
	<b>T3</b>	-.072	-.076	.124	1	.393	-.595
	<b>T4</b>	-.081	-.680*	-.187	1	-.224	.060
<b>Grain yield [kg/ 10<sup>2</sup> m<sup>2</sup>]</b>	<b>T1</b>	-.479	.081	-.381	-.575	1	-.253
	<b>T2</b>	-.344	.278	.309	-.206	1	-.532
	<b>T3</b>	-.163	.514	-.395	.393	1	-.270
	<b>T4</b>	-.286	.142	.345	-.224	1	.382
<b>Straw yield [kg/ 10<sup>2</sup> m<sup>2</sup>]</b>	<b>T1</b>	.387	-.539	-.157	.495	-.253	1
	<b>T2</b>	.286	.162	-.542	-.406	-.532	1
	<b>T3</b>	.357	-.142	-.236	-.595	-.270	1
	<b>T4</b>	-.543	-.552	-.100	.060	.382	1

\*Significant at the  $p \leq 0.05$  level

Correlation study (Table 3) among few variables (number of effective tillers per plant, LAI, ear length, grain per ear, grain yield, and straw yield) for each of the treatments (T1, T2, T3, and T4) exhibited positive or negative correlations between the variables under study, but these were not statistically significant.

Significant negative were found only in two cases, including LAI vs. the number of effective tillers per plant in treatment T1 and LAI vs. Grain per ear in treatment T4. As the overall correlation coefficients were not statistically significant, observation of the correlation study was not helpful in explaining the phenomena of significant difference of the variables across various treatments. Kaur *et al.* (2017) observed that growth parameters are significantly

correlated with vegetation indices at the booting stage of wheat. Thus, the overall observation from correlation statistics of current research is not corroborating with the finding of Kaur *et al.* (2017).

The experimental design of the current research was based on the RD of NPK (N- 120 Kg. ha<sup>-1</sup>, P<sub>2</sub>O<sub>5</sub>- 60 Kg. ha<sup>-1</sup>, K<sub>2</sub>O- 40 Kg. ha<sup>-1</sup>). It was focused on keeping the nitrogen supplement almost the same (about 120 kg. ha<sup>-1</sup>) in various treatments where vermicompost was used to replace chemical fertilisers in specific proportions. It is true that the nitrogen content in the vermicompost and the actual availability of nitrogen from the applied vermicompost in

field conditions are not the same. The availability of nitrogen from the vermicompost is influenced by various factors like the presence of microbes in the soil, its water content, etc. Hence, the addition of vermicompost will enhance a certain percentage of nitrogen to fulfil the amount of nitrogen as per the recommended dose might not always be correct. Besides, vermicompost contains nitrogen and other elemental nutrients essential for the plant's growth and yield. Another important limitation of the present research is the non-inclusion of 100% nitrogen supplement through vermicompost. Incorporation of this treatment and its comparison with other treatments under study would have revealed some valuable information.

#### IV. CONCLUSION

Observations of the present experiment conclude that utilisation of vermicompost for partial substitution of chemical fertilisers does not only facilitate the test weight, grain per ear, ear length, etc. and thereby higher crop yield of wheat but also impart a positive impact on straw yield.

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Different parameters such as number of effective tillers per plant, ear length, number of grains per ear, test weight, grain yield, and straw yield of the wheat crop were significantly higher when 50% of RD through chemical fertilisers and 50% of nitrogen through vermicompost were applied. Because in this treatment, an almost equal amount of nitrogen supply from both organic and inorganic sources helps to get a better result. This is due to the fact that the applied vermicompost supplied nitrogen and other major plant nutrients along with various micronutrients to the crop. Finally, it can be concluded that a mixture of organic and inorganic nutrients assists in improving soil fertility, which is reflected by the exceeding crop production if compared with the sole application of chemical fertilisers.

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