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Evaluation of Wheat (*Triticum aestivum* L.) under Inorganic and Organic Fertilization Using FTIR Spectroscopy

Rashpinder Singh[1], Manish Bakshi[2*], Kuljeet Singh[1], Sarwan Singh[1] and Terwinder Singh Brar[1]

[1]*Department of Agronomy, Lovely Professional University, Punjab, India*
[2]*School of Agriculture, Lovely Professional University, Punjab, India*

**Corresponding author*

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ABSTRACT

Studies were conducted to evaluate the effect of inorganic and organic fertilization on growth, yield of wheat and nutrient status of the soil**.** Significant differences in the vegetative growth parameters *viz.* plant height, number of green leaves, number of tillers/meter row length and yield parameters *viz.* Spike length, number of spikelets per spike, number of grains/ear, number of ear heads/m^2, test weight, straw yield and biological yield was highest under the application of 50 % recommended dose of fertilizers along with application of 5 t/ha vermicompost (T_7). Maximum seed yield per meter square (0.630 gm/m^2), grain yield (62.80 q/ha) was recorded with the application of RDF@75% +2.5 t/ha vermicompost (T_6). Maximum harvest index (66.76) was recorded with the application of RDF@125% (T_4). FTIR analysis of the wheat grains revealed maximum area under peaks for amines under the treatment T_5. Soil properties were evaluated and maximum available nitrogen (222.63kg/ha), available potassium (228.01 kg/ha) and organic carbon (0.79 kg/ha) was recorded under treatment T_6 (RDF@75% + 2.5 t/ha vermicompost). Maximum available phosphorus (22.17 kg/ha) was recorded under the treatment T_7 (application of RDF @50% + 5 t/ha vermicompost). Application of 50 % recommended doze of nitrogen along with application of vermicompost @5 t/ha gave the highest growth and yield response in wheat. However, soil parameters were at par in all the treatments involving integration of nutrients. Maximum benefit cost ratio was obtained by using recommended doze of fertilizers.

Introduction

Wheat (*Triticum aestivum* L.) is a predominant winter (rabi) crop of northwestern plain zone and central zone of India. It is the most important food crop in India (after rice) and occupies an area of 302.27 lakh hectares with a total production of 93.50 million tonnes (Anonymous, 2016). Intensive use of these chemical fertilizers in wheat production have resulted in to numerous problems like micro-nutrient deficiencies, nutrient imbalance in soil and plant system, increased pest infestation, environmental degradation, deterioration of soil health and stagnation of the crop yield. Over the past decade, India has exhibited a rapid uptake of organic farming but keeping in view the nutrient availability in organic fertilizers, total dependence on organic fertilizers to fulfill the crop nutrient demands is not possible. Integrated nutrient supply is the systematic approach to nutrient management as the combined application of organic and inorganic sources of nutrients improves the soil fertility and crop productivity (Shree *et al.,* 2014). Organic carbon is the main building block of soil fertility and combined application of organic and inorganic fertilizers increases higher soil organic content (Nkonya *et al.*, 2005, Marin *et al.,* 2007). In this context, it is imperative to adopt those agriculture technologies and methodologies which can improve the production of crop without deteriorating soil health.

Materials and Methods

The present investigation was carried out at the Departmental farms of Lovely Professional University, Punjab during the rabi season 2017-18 to evaluate the effect of organic and inorganic fertilization on growth and quality of wheat. The soil experimental field was sandy loam in texture, well fertile, acidic in reaction with good drainage. The experiment was divided in to seven treatments replicated thrice and laid out in a Randomized Block design. Wheat variety HD3086 was used at a recommended seed rate of 98.8 kg/ha. Treatments comprised of T_1: Control, T_2: RDF, T_3: RDF + 2.5t/ha vermicompost, T_4: RDF @ 125%, T_5: RDF @125% + 2.5 t/ha vermicompost, T_6: RDF @ 75% + 2.5 t/ha vermicompost and T_7: RDF @ 50% + 5 t/ha vermicompost. Seed rate, fertilizer doze and cultural practices followed were as per the recommended package of practices for wheat (Anonymous, 2013). Thoroughly prepared vermicompost was used and the total requirement of the crop was calculated on nutrient equivalent basis. Observations were recorded on growth and yield parameters using standard methods. Soil samples from each treatment were analyzed for soil nutrient analysis. Organic carbon was estimated using Walkley and Black's Method (Piper, 1966). Available nitrogen was estimated using Alkaline Potassium Permanganate Method (Subbiah and Asija, 1956). Available phosphorus was estimated by Olsen's Method (Olsen *et al.,* 1954) and available potassium was estimated by Flame Photometer (Mervin and Peech, 1951).

FTIR spectroscopic analysis

Fourier Transform Infra-red Spectroscopy (FTIR) was performed to evaluate the effect of different integrated nutrient management treatments on quality of wheat. Flour of wheat from each treatment was collected. These flour samples were converted into pellets and pellets were cut into thin sections. These thin sections were oven dried and their spectra were recorded on FTIR Spectroscope (SHIMADZU).

Statistical analysis

The data generated during the course of study was subjected to analysis of variance (ANOVA) and Duncan's multiple–ranged test was performed using SPSS v. 16 software to identify the homogeneous type of the data sets among different treatments for different plant parameters.

Results and Discussion

Vegetative parameters of wheat crop are presented under Table 1. Maximum plant height (58.07 cm), number of green leaves (4.87) and number of tillers/meter row length (82.20) was recorded with the application of RDF @ 50% + 5 t/ha Vermicompost (T_7). Wheat plants recorded maximum length of spike (13.73 cm), number of spikelets per spike (11.67) and maximum number of grains/ear (29.33) was recorded with the application of RDF @ 50% + 5 t/ha vermicompost (T_7). Maximum number of ear heads/m^2 (325.67) was recorded with the application of RDF @ 125% (T_4) whereas minimum number of ear heads/m^2 (215.67) was recorded under control (Table 2). Maximum test weight (45.97g) of wheat crop in rabi season under different nutrient management treatments was recorded with the application of RDF @ 50% + 5 t/ha vermicompost (T_7). Maximum seed yield per meter square (0.630 gm/m^2) and maximum grain yield (62.80 q/ha) was recorded with the application of RDF @ 75% + 2.5 t/ha vermicompost (T_6) whereas minimum seed yield per meter square was recorded under treatment T_1 (Table 3). Straw yield (45.80 q/ha) and biological yield (105.44 q/ha) was obtained maximum under the application of 50 % recommended dose of fertilizers along with application of 5 t/ha vermicompost (T_7). Maximum harvest index (66.76) was recorded with the application of RDF @ 125% (T_4).

Table 4 reveals that there was no significant effect on soil pH when compared to the initial pH values. Soil electrical conductivity was recorded maximum (0.17 dSm^{-1}) in treatment T_4 (application of RDF @ 125%). Maximum available nitrogen (222.63kg/ha), available organic carbon (0.79 kg/ha) and available potassium (228.01 kg/ha) was recorded under treatment T_6 (RDF @ 75% + 2.5 t/ha vermicompost). Maximum available phosphorus (22.17 kg/ha) was recorded under the treatment T_7 (application of RDF @ 50% + 5 t/ha vermicompost).

Fourier transform Infra-red spectroscopy (FTIR) was performed for evaluation of quality components in wheat grains under different treatments. The data presented in Table 5 reveals that the all the treatments showed the presence of different compounds but the main constituent of interest is the protein content in wheat. The data presented herein reveals the presence of peaks for amines (principal constituents of proteins) in all the samples but maximum area under the peaks was observed under the treatment T_5 which reflects that the application of recommended dose of fertilizers @ 125% along with augmentation of vermicompost @ 2.5t/ha significantly provided more nitrogen to the developing wheat grains which in turn is reflected as a greater proportion of amines in the spectroscopic analysis (Fig. 1).

Effect of various treatments on cost benefit ratio of wheat cultivation is presented in Table 6. Treatment comprising of cent per cent application of RDF @ 50% + 5 t/ha vermicompost (T_7) recorded maximum total cost of cultivation (₹ 85220.62) followed by ₹ 69972.6 obtained under treatment comprising of application of RDF@ 125% + 2.5 t/ha vermicompost (T_5). Lowest cost of cultivation (₹ 42749.18) was recorded under control (T_1). Maximum gross returns were recorded under the treatment comprising of application of RDF @ 75% + 2.5 t/ha vermicompost wherein a return of ₹116081was realized followed by treatment T_7 which recorded a gross return of ₹113110 per hectare. Minimum amount of gross returns (₹66280) were recorded under control (T_1). The table further revealed that net returns were highest (₹ 55636.00) under treatment where wheat plants were applied with recommended dose of fertilizers (T_2) followed by net returns of ₹ 51292.00 obtained under treatment T_4 (application of RDF@ 125%). Lowest net returns (₹ 24030.00) were obtained under control. Maximum benefit cost ratio of (2.1) was obtained under treatment comprising application of recommended dose of fertilizers (T_2) followed by benefit cost ratio of 2.0 and 1.8 obtained under treatment T_4 and T_6, respectively. Lowest benefit cost ratio of 1.3 was obtained under treatment comprising of application of RDF @ 50% + 5 t/ha vermicompost (T_7).

Table.1 Effect of integrated nutrient management on vegetative growth characters of wheat

Treatments	Plant height (cm)			Number of green leaves	Number of tillers/meter row length
	30 DAS	60 DAS	90 DAS		
T_1	23.41[bc]	35.7[cd]	52.07[a]	4.20[a]	65.53[a]
T_2	20.83[a]	33.0[ab]	56.79[b]	4.53[abc]	73.00[b]
T_3	22.83[b]	35.1[c]	55.20[b]	4.40[ab]	70.20[ab]
T_4	22.97[b]	36.2[d]	55.63[b]	4.40[ab]	73.27[b]
T_5	19.53[a]	32.4[a]	51.57[a]	4.73[bc]	70.13[ab]
T_6	24.80[d]	39.7[e]	57.60[b]	4.73[bc]	73.00[b]
T_7	25.13[de]	41.5[f]	58.07[b]	4.87[c]	82.20[c]
S. Em. (±)	0.29	0.40	1.32	0.10	1.80
C.D. (5%)	0.92	1.27	2.91	0.32	5.62

Treatments: T_1: Control, T_2: RDF, T_3: RDF + 2.5t/ha Vermicompost, T_4: RDF @ 125%, T_5: RDF @125% + 2.5 t/ha Vermicompost, T_6: RDF @ 75% + 2.5 t/ha Vermicompost, T_7: RDF@ 50% + 5 t/ha Vermicompost

Table.2 Effect of integrated nutrient management on yield characters of wheat

Treatments	Spike length (cm)	Spikelets/spike	Number of grains/ear	Number of ear heads per m^2
T_1	9.40[a]	8.33[a]	25.00[a]	215.67[a]
T_2	10.20[b]	9.33[b]	27.00[abc]	294.33[b]
T_3	10.10[b]	9.33[b]	26.00[ab]	287.33[b]
T_4	10.20[b]	9.67[bc]	26.67[abc]	325.67[c]
T_5	9.93[a]	8.33[a]	28.33[bc]	291.67[b]
T_6	12.80[c]	10.67[d]	28.00[abc]	300.00[b]
T_7	13.73[d]	11.67[e]	29.33[c]	302.33[b]
S.E m(±)	0.21	0.37	0.68	6.17
C.D (0.05)	0.68	1.17	2.12	19.24

Treatments: T_1: Control, T_2: RDF, T_3: RDF + 2.5t/ha Vermicompost, T_4: RDF @ 125%, T_5: RDF @125% + 2.5 t/ha Vermicompost, T_6: RDF @ 75% + 2.5 t/ha Vermicompost, T_7: RDF@ 50% + 5 t/ha Vermicompost

Table.3 Effect of integrated nutrient management on yield characters of wheat

Treatment	Test weight (g)	Seed weight (g/m^2)	Grain yield (q/ha)	Straw yield (q/ha)	Biological Yield (q/ha)	Harvest Index (HI)
T_1	41.90^{ab}	0.34^{a}	34.37^{a}	31.00 ^{ef}	65.37 ^{d}	52.58 ^{a}
T_2	42.87^{bc}	0.56^{bc}	55.53^{bc}	43.81 ^{c}	99.34 ^{a}	55.90 ^{ab}
T_3	44.43^{cd}	0.49^{b}	48.87^{b}	45.73 ^{b}	94.61 ^{a}	51.66 ^{a}
T_4	40.53^{a}	0.55^{bc}	54.80^{bc}	27.29 ^{g}	82.09 ^{d}	66.76 ^{b}
T_5	44.83^{cd}	0.55^{bc}	54.80^{bc}	37.95 ^{d}	92.75 ^{b}	59.08 ^{ab}
T_6	45.93^{d}	0.63^{c}	62.80^{c}	33.13 ^{e}	95.93 ^{bc}	65.46 ^{b}
T_7	45.97^{d}	0.60^{bc}	59.50^{bc}	45.8 ^{ab}	105.44 ^{a}	56.43 ^{ab}
S.Em (±)	0.63	0.02	2.08	0.09	0.13	2.28
C.D. (5%)	1.98	0.06	6.49	0.29	0.42	7.11

Treatments: T_1: Control, T_2: RDF, T_3: RDF + 2.5t/ha Vermicompost, T_4: RDF @ 125%, T_5: RDF @125% + 2.5 t/ha Vermicompost, T_6: RDF @ 75% + 2.5 t/ha Vermicompost, T_7: RDF@ 50% + 5 t/ha Vermicompost

Table.4 Effect of integrated nutrient management on nutrient availability status of the soil

Treatment	Soil pH	EC (dS/cm^2)	Available N	Available P	Available K	Available OC
T_1	6.56^{a}	0.11^{a}	203.87^{a}	16.03^{a}	174.35^{a}	0.42^{a}
T_2	6.84^{a}	0.16^{b}	213.23^{c}	18.07^{b}	227.13^{f}	0.66^{c}
T_3	7.03^{a}	0.14^{ab}	210.10^{b}	22.03^{c}	214.63^{c}	0.75^{d}
T_4	6.95^{a}	0.17^{bc}	217.07^{d}	21.87^{c}	222.69^{e}	0.55^{b}
T_5	7.36^{a}	0.12^{c}	218.43^{d}	21.20^{c}	219.23^{d}	^{a}0.69^{c}
T_6	7.48^{a}	0.13^{d}	222.63^{f}	21.63^{c}	228.01^{f}	0.79^{e}
T_7	7.70^{a}	0.13^{d}	219.53^{e}	22.17^{c}	208.97^{b}	0.76^{de}
S.E (m)	0.09	0.003	0.84	0.36	0.77	0.01
C.D	0.30	0.01	2.62	1.13	2.42	0.03

Treatments: T_1: Control, T_2: RDF, T_3: RDF + 2.5t/ha Vermicompost, T_4: RDF @ 125%, T_5: RDF @125% + 2.5 t/ha Vermicompost, T_6: RDF @ 75% + 2.5 t/ha Vermicompost, T_7: RDF@ 50% + 5 t/ha Vermicompost

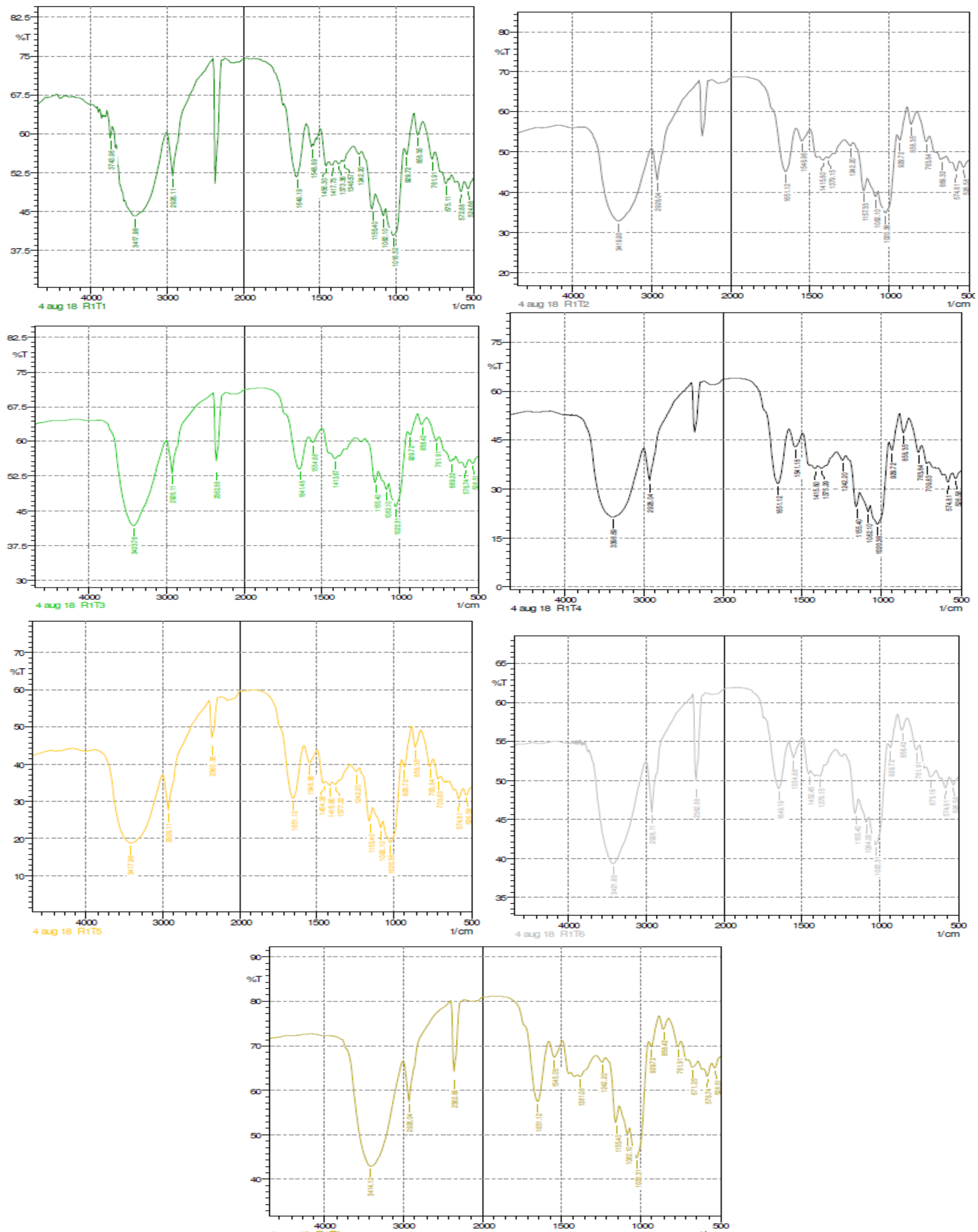
Table.5 FTIR spectroscopic analysis of wheat under different integrated nutrient management treatments

	T_1		T_2		T_3		T_4		T_5		T_6		T_7		Compound
	Peak	**Area**	**Peak**	**Area**	**Peak**	**Area**	**Peak**	**Area**	**Peak**	**Area**	**Peak**	**Area**	**Peak**	**Area**	
1	524.66	9.2	526.58	16.44	528.51	12.68	526.58	22.50	526.58	23.44	526.58	15.70	528.51	9.02	C-Br stretch
2	572.88	14.5	574.81	16.68	576.74	13.45	574.91	23.85	574.81	24.72	574.81	14.65	576.74	9.58	C-Br stretch
3	675.11	15.03	669.32	13.80	689.32	7.78	709.93	18.49	709.83	20.23	673.18	11.38	671.25	8.74	C–H bending (Alkynes)
4	761.91	18.86	763.84	20.43	761.91	16.56	763.84	27.49	763.84	28.50	761.91	20.14	761.91	11.19	Out-of-plane C–H bending
5	858.35	11.88	858.35	13.39	856.42	10.65	858.36	17.64	858.35	19.54	856.42	14.91	856.42	7.20	β-D-sucrose
6	929.72	14.50	929.72	15.91	929.72	12.66	929.72	21.98	929.72	22.98	929.72	15.61	929.72	9.08	β-D-cellulose
7	1016.52	43.30	1020.38	49.44	1022.31	36.33	1020.38	73.76	1020.38	76.30	1022.31	42.21	1022.31	34.52	Cellulose and phenols
8	1082.1	22.09	1082.1	25.50	1082.1	19.00	1082.1	37.59	1082.1	39.06	1084.03	22.17	1082.1	17.59	Cellulose and phenols
9	1155.4	26.48	1157.33	29.76	1155.4	22.30	1155.4	34.39	1155.4	44.55	1156.4	27.51	1155.4	19.46	Cellulose and phenols
10	1242.2	13.30	1242.2	15.77	-	-	1242.2	23.14	1242.2	23.00	-	-	1242.2	10.38	Hemicelluloses and phenols
11	1373.36	18.34	1379.15	13.16	-	-	1375.29	21.00	1377.22	21.95	1379.15	8.94	1381.08	21.88	Aromatic nitro compound NO_2 symmetric stretching
12	1417.73	11.17	1415.8	15.78	1413.87	13.29	1415.8	20.18	1415.8	20.31	-	-	-	-	Amine
13	1456.3	12.77	-	-	-	-	-	-	1454.38	23.28	1452.45	14.57	-	-	Amine
14	1548.89	7.14	1546.96	23.54	1554.68	18.59	1541.18	30.11	1546.96	31.69	1554.68	7.26	1545.03	13.88	Amine
15	1649.19	35.24	1651.12	63.90	1641.48	34.83	1651.12	94.99	1651.12	**103.53**	1649.19	23.07	1651.12	41.57	Amine
16	-	-	-	-	2362.98	10.84	-		2360.95	13.75	2362.88	14.56	2362.88	8.36	Saturated carbons
17	2926.11	110.84	2928.04	144.69	2926.11	32.16	2928.04	182.59	2926.11	213.35	2926.11	40.20	2928.04	85.84	Saturated carbons
18	3417.98	31.94	3419.9	288.85	3423.76	217.14	3398.69	5.16	3417.98	466.91	3421.83	147.29	3414.12	201.34	O–H stretching (water)
19	3743.96	10.05	-	-	-	-	-	-	-	-	-	-	-	-	Amide N-H Stretch

Table.6 Effect of different integrated nutrient management on economics of wheat cultivation

	T_1	T_2	T_3	T_4	T_5	T_6	T_7
FIXED COST							
LAND RENT	25000	25000	25000	25000	25000	25000	25000
VARIABLE COST							
Cost of seed	2568.8	2568.8	2568.8	2568.8	2568.8	2568.8	2568.8
Cost of fertilizers	0	5739.5	24489.5	7174.3	25924.3	23054.6	40369.7
Cost of spraying	2512.5	2512.5	2512.5	2512.5	2512.5	2512.5	2512.5
Cost of labour	600	1200	1200	1200	1200	1200	1200
Cost of preparation.	2070	2070	2070	2070	2070	2070	2070
Cost of harvest.	2250	2250	2250	2250	2250	2250	2250
Cost of irrigation	4140	4140	4140	4140	4140	4140	4140
Cost of husk	3107.88	4400.41	4588.62	2738.39	3807	3324.03	4609.62
Total	**42749.18**	**50381.21**	**69319.42**	**50153.99**	**69972.6**	**66619.93**	**85220.62**
RETURN							
Avg. Yield	34.36	55.33	48.86	54.8	54.8	62.8	59.5
Selling price/q	1735	1735	1735	1735	1735	1735	1735
Yield income	**59614.6**	**95997.55**	**84772.1**	**95078**	**95078**	**108958**	**103232.5**
Husk income/ha	6665	9420	9833.33	5868.33	8160	7123.33	9878.33
Gross income	**66279.6**	**105417.6**	**94605.43**	**100946.3**	**103238**	**116081.3**	**113110.8**
RETURN STRUCTURE							
Gross income	66279.6	105417.6	94605.43	100946.3	103238	116081.3	113110.8
Total cost of culti.	42749.18	50381.21	69319.42	50153.99	69972.6	66619.93	85220.62
NET RETURN	**24030.42**	**55536.39**	**25786.01**	**51292.31**	**33765.4**	**49961.37**	**28390.18**
B:C RATIO	**1.6**	**2.1**	**1.4**	**2.0**	**1.5**	**1.8**	**1.3**

Fig.1 FTIR characterization of wheat under different inorganic and organic fertilizer treatments



Wheat crop under the experiment performed better for vegetative parameters with the application f both inorganic and organic sources of fertilizers. Better performance of wheat plant under the effect of combined application of inorganic and organic fertilizers may be due to the fact that organic manures ensured longevity in supply of nutrients which resulted in stimulation of cell division and elongation of internodes (Zaki *et al.*, 2012). Similar findings have been reported by Cherr *et al.*, (2006). Many researchers reported that combined application of manures and fertilizers increased the plant height and tillers hill^{-1} (Khan *et al.*, 2007), spike length, (Singh *et al.*, 2011) and filled grains spike^{-1} (Satyannarayana *et al.*, 2002). Increase in grain yield is a function of nutrient availability to the plants. Under the current experiment, organic matter like vermicompost has supplied nutrients to the plants providing a favourable soil environment and increased water holding capacity of the soil. Increased straw yield per ha under treatment T_7 may be attributed to the fact that maximum vegetative growth was also recorded under the same treatment as reported by Brar *et al.*, (2015) in pearl millet-wheat cropping system.

It was observed that treatments involving the application of inorganic fertilizers were high on EC values due to availability of nutrient ions as reported by (Krishna *et al.*, 2004). Elevated nutrient status of the soil under the application of inorganic and organic sources of fertilizers can be attributed to the fact that organic manures are the sink of nutrients that is available in soil for a longer duration as reported by Singh *et al.,* (2008). Singh *et al.*, (2013) also reported similar findings wherein availability of phosphorus in the soil increased with the combined application of fertilizers and manures as compared to cent per cent application of NPK due to solubalization of naïve P in the soil under the effect of released organic acids from organic manures.

Highest amount of protein content in the treatment involving RDF@125 + 2.5 t/ha Vermicompost is due to the availability of nitrogen in a bounty which was reflected in the grains. The economics of cultivation was highest under RDF dose primarily due to the fact that incorporation of organic manures increased the cost of production.

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