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Comparative effect of organic and inorganic sources of nutrients on yield, soil properties, and economics of wheat under rice-wheat cropping system

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A field experiment was conducted to evaluate the effect of various organic nutrient sources on wheat production, soil properties and economics of wheat crop at Kurukshetra, Haryana, during the *rabi* season of 2018-19. The experiment was laid out in a completely randomized block design with a total of eight treatments based on different organic nutrients sources. Experimental results demonstrated that yield contributing parameters such as the number of effective tillers, grains per spike, test weight and spike length were significantly higher in T_7 (RDF) followed by in T_2 (FYM @ 15 t/ha), T_1 (Vermicompost @7.5 t/ha) and other cow-based nutrient sources. Significantly higher net returns (₹ 31508 /ha) and Benefit-cost ratio (1.39) were documented in T_7 followed by in T_1 and T_2, respectively. Application of different organic formulations significantly improved microbial count (total bacterial, total fungi, azotobacter, phosphorus solubilizing bacteria and potassium solubilizing bacterial count) in the soil rhizosphere over the inorganic source of nutrients. Due to stimulation of soil microbial activity by the application of various organic nutrient sources significantly improved the available NPK status of the soil and biological activity in the soil. Among various organic treatments, the highest available nitrogen and phosphorous were recorded under vermicompost applied plots whereas, the highest available potassium was recorded in Farm Yard Manure (FYM) treated plots. Hence, organic sources can be a suitable alternative over inorganic nutrient sources to sustain crop yield and productivity of the soil over a longer period of time.

Keywords: Cow-based formulations, Inorganic fertilizers, Microbial population, Organic nutrient, Soil health, Wheat

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Wheat (*Triticum aestivum* L.), a member of the Poaceae (Gramineae) family, is the world's most valuable staple cereal crop after paddy and contributes significantly to the global economy. It provides nourishment to 35% world's population and plays a vital role in maintaining food and nutritional security at the national and global levels. Wheat is the cultural base or foundation of nourishment because it contains carbohydrates (60-80%), protein (approx.12%) and rich in catalytic elements, mineral salts, Ca, Mg, K, S, Mn, Cu, Zn and Vitamin B, K and E. The total area, production and productivity of wheat in India were 31.45 million hectares (22.4% area of total cultivated area), 107.59 million tonnes and 3425 kg ha^{-1}, respectively during 2019-20. Haryana is one of the leading wheat producing states of India where 13.27 million tonnes of wheat was produced (10.77% of total wheat production) from an area of 2.52 million hectares (8.24% of the total area under wheat cultivation at the national level) with a productivity of 5265 kg ha^{-1} (2nd highest after Punjab in India) during 2019-20[1].

At the global level, the “green revolution” brings a huge change especially in terms of both area and production of cereals that started in 1940 and found its peak in the 1960s. With the advent of the green revolution in India during the 1960s, the production and productivity of wheat increased at a high level, which was achieved due to over-reliance on high yielding cultivars, synthetic fertilizers, insecticides, weedicides and farm mechanization that resulted in heavy pressure on our natural resource base[2]. Excessive use of chemically synthesized straight fertilizers, agro-chemicals, and other unsustainable cropping practices have an adverse effect on nature, this results in a net negative nutrient balance and ultimately leads to a decline in soil fertility and productivity by impairing the soil health. The excessive use of chemicals over time has started posing problems to different forms of life including human health due to the persistence of residues in food items. Synthetic chemicals have long residual

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life in the soil which harms the beneficial soil microbes and fauna resulting in the degradation of soil fertility[3]. Consequently, in recent years farming practices have been changing and organic farming has emerged as a good substitute for inorganic chemical farming for sustainable development. Declining factor productivity, worldwide energy crisis and high increment in the price of synthetic fertilizers had led to the present focus on supplementation or replacement of inorganic fertilizers with low priced nutrition sources such as organic compost and manures[4]. Adding different organic origin nutrients in the soil such as organic manure, bio-compost and FYM will be effective in further improving productivity sustainably. Continuous utilization of organic supplies of nutrients and efficient crop production principles can be used to ensure an optimal amount of soil organic carbon for sustaining production and soil productivity[5].

In the era of intensive agriculture, organic agriculture helps in bringing a healthy and sustainable agriculture system which is the need of the hour. In the 21st century popularity of organic farming is continuously increasing along with a substantial increase in the organic food product markets at both the global and national levels[6]. Due to the growth of the organic market, it becomes more convenient for growers to sell their organic produce at higher premium prices. For organic farming, nutrient application and their management in the field is the most important practice during crop growth stages. It is a need of an hour to focus more on organic-rich nutrient sources and methods for enhancing the fertility status of organic farms, more specifically during the starting years of organic farming.

By enhancing the physico-chemical properties of soil, the addition of bulky organic manures such as FYM and vermicompost improves the soil nutrient status and supply of nitrogen and phosphorus[7]. Food quality of organically grown produce can be maintained by the application of vermicompost as a source of nutrients[8]. In addition to a sustainable increase in crop yield, organic sources are also needed to maintain the soil fertility status[9]. The philosophy of organic agriculture is to promote the growth and development of soil micro-flora and fauna without using any external chemical fertilizer and any agro-chemical. Soil micro-organisms have a crucial and active role in maintaining and restoring soil health, as they are involved in the recycling of macronutrients, micronutrients, and beneficial nutrients which are vital for the overall plant growth and development[10]. They also participate in the decomposition of organic matter, which aids in the mineralization and immobilization of nutrients.

Indian agriculture has been cow-centric from ancient times. Emphasis is being given to developing sustainable desi cow-centric farming system models in the present times also. The cow-based organic nutrient formulations prepared from the dung and urine of cows are being used as nutrient sources by several workers as sources of nutrients for crops. Under zero budget natural farming, the soil is supported with cow-based nutrient formulations like *jivamrit, ghanjivamrit* and *beejamrit* to increase the proliferation of soil micro-fauna and flora, which improves the soil fertility status. Microbial count and enzymatic activities were highest under the *Javik Krishi* inputs such as Panchgavya[11]. Collecting and gaining traditional knowledge and practices about organic farming from local farmers across the globe is worth validating and exchanging with the different regions of the world to make organic farming more sustainable[12]. As the scientific information regarding the productivity, of pure organic cultivation and the effect of cow-based nutrient formulations on soil properties, is lacking, therefore, this field experiment aimed to determine the impact of organic nutrient sources on yield, economics and soil properties.

Materials and Methods

Experimental site

During the *rabi* season of 2018-19, a field experiment was conducted at *Gurukul Farm* (located at 29°57' latitude and 76°48' longitude at an elevation of 258 m above mean sea level), Kurukshetra, Haryana, India. The experimental site falls under the Trans Gangetic plain (Rice-wheat cropping system)and irrigation management was done by tube well. The soil belongs to the clay loam textural class and other initial chemical and microbiological parameters were studied by collecting soil samples before sowing of crop using standard methods and obtained results are given in Table 1.

Treatment details

The experiment included eight treatments, which are described in detail in Table 2. Ingredients and nutrient composition (%) of organic sources of nutrients on a dry weight basis are given in Table 3.

Table 1 — Initial properties of soil (0-15 cm) at the experimental site

Particulars	Mean value	Method Used
A. Mechanical composition		
1) Sand (%)	21.50	International pipette method[27]
2) Silt (%)	42.80	
3) Clay (%)	34.70	
4) Soil texture	clay loam	
B. Chemical properties		
1) pH (1:2, soil: water)	7.7	pH meter[28] (Jackson, 1973)
2) Electrical conductivity (dS m^{-1}) (1:2 soil: water)	0.36	Conductivity bridge method[29] (Richards, 1954)
3) Organic carbon (%)	0.29	Walkley and Black[28] (Jackson, 1973)
4) Available N (kg ha^{-1})	126.4	Alkaline permanganate method[30]
5) Available P_2O_5 (kg ha^{-1})	16.2	Olsen's method[31]
6) Available K_2O (kg ha^{-1})	252.3	Flame photometric method[29]
7) DTPA-extractable Zn (ppm)	1.5	Atomic Absorption Spectrophotometer[32]
C. Microbial properties		
1) Total Bacterial population at sowing (CFU x 10^6 per g dry soil)	1.75	Standard serial dilution plate count method using nutrient agar media
2) The total fungal population at sowing (CFU x 10^4 per g dry soil)	7.84	Standard serial dilution plate count method using czapek media
3) Diazotrophic (Azotobacter) population at sowing (CFU x 10^5 per g dry soil)	8.34	Standard serial dilution plate count method using Jensen's nitrogen-free agar media
4) Phosphorus solubilizing bacteria (PSB) population at sowing (CFU x 10^5 per g dry soil)	5.89	Standard serial dilution plate count method using pikovskaya's media
5) Potassium solubilizing bacteria (KSB) population at sowing (CFU x 10^5 per g dry soil)	2.01	Standard serial dilution plate count method using aleksandrow agar media

Table 2 — Different sources of organic and inorganic sources of nutrients

Treatment	Description of Treatments
T_1	Farm Yard Manure (15 t/ha)
T_2	Vermicompost (7.5 t/ha)
T_3	Jivamrit soil application thrice (500 liters/ha, at pre-sowing irrigation, I & II irrigation)
T_4	Jivamrit soil application twice (500 liters/ha, at pre-sowing irrigation & I irrigation) + Jivamrit spray twice at 50-60 DAS and 80-90 DAS (500 liters/ha)
T_5	T_4+ Ghanjivamrit twice (150 kg/ha, Ground casting at I & II irrigation)
T_6	T_5+ Sapt Dhanya Ankur Ark spray (1.75 kg/ha in 500-liters water/ha one week after 50% heading)
T_7	Recommended dose of fertilizers (RDF): N-120, P_2O_5-60, K_2O-60 kg/h)
T_8	Control

Table 3 — Ingredients and nutrient composition (%) of organic sources of nutrients on a dry weight basis

Sr. No.	**Input**	**Ingredients**	**N P K (%)**
1.	Farm Yard Manure	Cow dung and agricultural by-products	0.62 - 0.18 - 0.55
2.	Vermicompost	10-15 days old cow dung, organic waste (farm litter and crop residues) Earthworms (*Eisenia foetida*)	1.61 - 0.90 - 1.10
3.	Jivamrit	Cow dung – 10 kg, Cow urine – 10 liters Jaggary – 2 kg, Legume flour – 2 kg Water – 200 liters, Handful of soil	0.75 - 0.16 - 0.33
4.	Ghanjivamrit	Cow dung- 100 kg, Jaggary – 1 kg Legume flour – 2 kg, Cow urine – as per needed, Handful of soil	1.51 - 0.40 - 1.12
5.	Sapt Dhanya Ankur Ark	Cow urine- 10 liters, Linseed- 100 g Green Gram- 100 g, Black gram- 100 g Cow Pea- 100 g, Turkish gram- 100 g Wheat seeds- 100 g, Chick Pea- 100 g Water- 200 liters	1.89 - 1.32 - 0.75

Agronomic operations schedule

Pre-sowing operations

Pre-sowing irrigation was applied on October 30, 2018, with tube well water. Application of pre-sowing nutrient treatments (T_3 and T_4) was done on November 7, 2018. HD 2967 variety of wheat was sown by seed drill at 22.5 cm row to row spacing. Seed rate @ 120 kg/ha was used for sowing the wheat crop and seed was placed at a depth of 5-6 cm on November 14, 2018. The final layout, channels, and bunds were prepared on November 16, 2018. Organic nutrients were applied as per treatments on January 2, 2019. At 35 and 55 days after sowing, two manual weedings were performed. Two irrigations were applied with tube water at 24 and 86 days after sowing. The crop was harvested manually just above the ground surface by using sickles from each treatment. Harvested crop plants were collected and transformed into a bundle and left for three days for sun drying. The biological yield of harvested crop plots was recorded from each plot of individual treatments. After sun drying threshing of the crop was done manually for each treated plot and grains collected from each net plot were weighted.

Plant observations

Plant height was measured by selecting five random plants from each net plot, tagging the selected plants and recording plant height at monthly intervals from sowing to harvest. For the measurement of plant height, length from the ground surface of plants to the base of the completely opened leaf before the heading stage and after the heading stage was taken up to the top point of the ear head of the main shoot was measured. The second row of the net plot from the border was labeled as a sampling row for the calculation of dry matter of crop plants from the individual treated plots. From this demarcated area for dry matter calculation, fresh crop plant samples were cut down from the ground surface in a one-meter row length at a periodic interval of 30 days up to the harvest of the wheat crop. After drying the plants in the oven to attain a steady weight at 60°C, the dry matter was measured. After weighing the dry matter of one-meter row length, the dry matter of one m^2 area was calculated. The number of tillers was counted at monthly intervals beginning on 30 DAS from one meter running row length and expressed as the number of tillers per square meter area. To calculate LAI (leaf area index) twenty-five-centimeter row length of wheat plants were cut down from the second row from two random places of a net plot from either side in each treated plot at a monthly interval from sowing to 90 days after sowing. For the estimation of LAI, wheat plant leaves were removed from the base of the lamina from each plant. Leaf area meter (L1 3000C Area meter) was used for the calculation of leaf area index. The below-mentioned formula was used for the calculation of leaf area index:

Leaf area index = Total leaf area (cm^2)/ Total land area (cm^2)

Yield attributes

At the time of harvest, the number of effective tillers per running meter row length was counted and translated into the number of effective tillers per square meter. Ten random plants were chosen for spike length estimation, and spike length was determined from the base of the lowest spikelet to the tip of the highest spikelet. The number of spikelets in each of the ten randomly chosen spikes was calculated, and the mean value was used to calculate the number of spikelets per spike. From the net treated plot, grain samples were collected and 1000 grains were counted from the collected samples. Sun drying of grain samples was done thoroughly and the weight of dried grains was recorded in grams. Sun-drying was done after harvesting and threshing of wheat grains from each net plot was completed. Grain weight per net plot is converted to kilograms per hectare (kg/ha). After sun drying of harvested produce weight of grain + straw that is biological yield(kg/ha) of the crop from each net plot was calculated on a weight basis. By subtracting the grain yield from the biological yield from net plots, straw yield (kg/ha) can be determined. The harvest index (HI) and attraction index (AI) were calculated by using the below-mentioned formula:

$$\text{Harvest index} = \frac{\text{Grain yield (kg/ha)}}{\text{Biological yield(kg/ha)}}$$

$$\text{Attraction index} = \frac{\text{Grain yield (kg/ha)}}{\text{Straw yield(kg/ha)}}$$

Soil chemical studies

After the wheat crop was harvested, soil samples were taken from each net treated plot at a depth of 0-15 cm to measure soil physical and chemical properties. Following the same protocol as in Table 1, these soil samples were dried and examined for pH, EC, OC, available nitrogen, phosphorus, potassium, and zinc by using suitable reagents used in standard procedures as mentioned in Table 1. Soil samples were obtained from the rhizosphere of the soil profile (0-15 cm) and the same technique as described in Table 1 was used for the estimation of soil microbial properties.

Soil microbiological studies

Soil samples were collected from the rhizosphere of the soil profile for counting microbial load present in the soil at sowing, 30, 60, 90, 120 DAS and harvest i.e., for the population of total soil bacteria, fungi, azotobacter, phosphorus solubilizing bacteria (PSB) and potassium solubilizing bacteria (KSB) by the standard serial dilution plate count method using nutrient agar media for bacteria, czapek media for fungi, Jensen's nitrogen free agar media for azotobacter, pikovskaya's media for phosphorus solubilizing bacteria (PSB) and Aleksandrow agar media for potassium solubilizing bacteria (KSB). Plates were incubated at 28±2°C in an incubator and colony counts were recorded after six days of incubation. The population was expressed as the number of colonies forming units per gram (cfu/g) dry weight of soil.

Economics

The cost of cultivation for each specific treatment was determined using the values of different agronomic activities and inputs used in that treatment. To calculate the gross returns, the minimum support price (₹1625 /q) and premium price of organic wheat (₹2785/q) was multiplied by grain yield and straw rate (₹ 450 /q) by straw yield and both were summed to find out the gross returns of each treatment (The base year 2017-18). The most profitable treatment was determined by calculating the economics of the various treatments used in the experiment in terms of net returns (₹/ha), which were measured by subtracting cultivation costs from gross returns per hectare. To determine the economic feasibility of particular treatments, the benefit-cost ratio was determined using the below-mentioned formula:

$$\text{B: C} = \frac{\text{Gross returns}}{\text{Cost of cultivation}} X100$$

Statistical analysis

The mean values of the repeated observations were used to calculate the experimental data for various growth, yield, and soil parameters (chemical and microbiological). The experimental data was statistically analyzed by using online computer software OPSTAT developed by the department of Maths, Statistics & Physics, CCSHAU, Hisar, Haryana[13].

Result and Discussion

Yield attributes and yield

The application of FYM, vermicompost and other cow-based nutrient formulations significantly affects the number of effective tillers per meter square, the number of grains per spike, spike length and 1000-grain weight (Table 4). T_7 has the maximum number of effective tillers (381.6 per m^2), the number of grains per spike (44.7), spike length (12.2 cm), test weight (34.8 g), grain yield (4986 kg/ha) and straw yield (7130 kg/ha), which were statistically superior to all other treatments. Among organic nutrient sources, T_2 recorded the maximum number of tillers (326.1 per m^2), number of grains per spike (41.5), spike length (10.8 cm), test weight (33.3 g) and grain

Table 4 —Effect of nutrient sources on yield attributes of wheat

Treatments	Number of effective tillers per m^2	Number of grains per spike	Spike length (cm)	1000- grain weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Harvest index (%)	Attraction index (%)
T_1	298.3	39.9	10.6	32.8	3426	4910	41.1	69.7
T_2	326.1	41.5	10.8	33.3	3646	5250	40.1	69.4
T_3	226.5	36.7	9.8	30.5	2675	3718	41.8	71.9
T_4	244.6	37.1	10.2	30.8	2785	3955	41.3	70.4
T_5	260.9	37.8	10.3	31.4	3043	4443	40.6	68.4
T_6	279.8	38.5	10.4	31.9	3142	4681	40.1	67.1
T_7	381.6	44.7	12.2	34.8	4986	7130	41.1	69.9
T_8	198.5	32.5	9.2	29.7	2133	3434	38.3	62.1
SEm ±	5.9	0.85	0.2	0.6	82.10	111.05	0.34	0.66
CD (p=0.05)	18.1	2.57	0.6	1.9	249.01	336.83	1.03	1.99

yield (3646 kg/ha) followed by T_1 which was significantly superior over all the cow-based organic nutrient formulations. The harvest index was in the range 38.3-41.8% and the highest harvest index was recorded in T_3 (41.8%). Similarly, the attraction index was in the range 62.1-71.9% and the highest attraction index was recorded in T_3 (71.9%). The grain and straw yield of a crop is dependent on the source-sink relationship, combined function of different growth components and yield attributing parameters.

The possible reason for higher yield attributing components in RDF is due to higher growth that is associated with easy availability of nutrients in the proper amount and available form as compared to less availability of nutrients due to the slow release of available nutrients from organic sources of nutrients, mainly in the initial year of the transition phase of organic farming[14]. Among organic nutrient sources, vermicompost treated plots documented the maximum yield and yield attributing parameters because of higher NPK content in vermicompost as compared to other organic sources which ultimately increased the growth, yield, and yield attributes of wheat crop[15]. Plant height, the number of tillers, grain yield, and test weight all increased dramatically when organic sources of nutrients including manures and compost were used instead of the control[16]. Yousefi and Sadeghi[17] also documented that when compared to other organic sources, vermicompost application greatly increases wheat production and yield characteristics.

Economic studies

The impact of FYM, vermicompost, and other cow-based nutrient formulations on cultivation cost, gross returns, net returns, and the B: C ratio is shown in (Table 5). The highest cost of cultivation (₹ 103004/ha) was incurred with T_2followed by T_1 (₹ 89420/ha). Similarly, the application of T_2 recorded the highest gross return (₹ 125130/ha) followed by T_1 (₹ 117510/ha). T_7 recorded the highest net returns (₹ 31508/ha) which was higher than all other treatments followed by T_1 (₹ 28090/ha), T_2 (₹ 22126/ha), and other cow based organic nutrient formulations. T_7 has the highest benefit-cost ratio (1.39), followed by T_1, T_2 and other sustainable cow-based nutrient formulations. Under control, the lowest cost of cultivation, gross returns, net returns and benefit-cost ratio were reported.

Owing to the higher purchasing cost of vermicompost relative to other sources of nutrients, T_2 had the highest cost of cultivation (₹ 103004/ha). T_2 recorded the highest gross return (₹ 125130/ha) followed by T_1. Though the yield in vermicompost treated plots was less as compared to RDF however, the premium price of organic wheat was significantly higher than inorganic wheat which resulted in higher gross returns in T_2 and T_1 as compared to T_7. T_7 recorded the highest net returns (₹ 31508/ha) followed by T_1 (₹ 28090/ha). The use of synthetic fertilizers in treatment T_7 results in lower cultivation costs and higher gross returns, which leads to higher net returns. Similarly, net returns per rupee spent followed the same trend as net returns from various other treatment options. In synthetic applied fertilizers benefit-cost ratio was higher than the organic applied fertilizers due to the lesser cost of cultivation[18,19].

Table 5 — Effect of nutrient sources on the economics of wheat crop

Treatments	Cost of cultivation (₹/ha)	Gross Returns (₹/ha)	Net returns (₹/ha)	B:C
T_1	89420	117510	28090	1.31
T_2	103004	125130	22126	1.21
T_3	83404	91404	8000	1.10
T_4	85539	95415	9876	1.12
T_5	87220	104619	17399	1.20
T_6	87738	108303	20565	1.23
T_7	81624	113132	31508	1.39
T_8	77000	74292	-2708	0.96

*Minimum support price of wheat @ ₹1625 /q (The base year 2017-18), Premium price of organic wheat (₹2785/q), Straw rate @ ₹450/q

Soil chemical studies

The use of FYM, vermicompost, and other cow-based nutrient formulations increased soil quality by enhancing soil nutrient status and improve soil physical, chemical and biological properties (Table 6). Chemical properties like pH, EC (dS/m) and organic carbon (g/kg) of soil were not altered under various nutrient sources throughout the crop season. The available nutrient status of soil was improved throughout crop growth. The application of various organic sources of nutrients greatly increased the abundance of different macro-nutrients such as nitrogen, phosphorus and potassium in the soil. T_2 (128.8 kg/ha) has the maximum available nitrogen, which was statistically comparable to T_1 (127.6 kg/ha), T_7 (125.4 kg/ha), and T_6 (123.6 kg/ha). Similarly, T_2 (16.9 kg/ha) had the highest available phosphorus and was substantially superior over the other nutrient sources. The highest available potassium was observed in T_1 (255.3 kg/ha), which was statistically at par with all the sources of nutrients. However, in untreated plots nutrients pool of macro and micro-nutrients was recorded lowest. The availability of soil zinc was not improved significantly by various sources of nutrients and all the nutrient sources were statistically at par with each other.

The status of NPK after crop harvest of crops significantly varies among the different nutrient source applications. The available nitrogen was found significantly highest in vermicompost treated plots followed by RDF and FYM respectively, whereas the lowest was reported under untreated plots.

The higher supply of soil nutrients after crop harvest may be due to the constant and gradual mineralization of organic manures during the crop seasons. Application of vermicompost and FYM recorded more available phosphorus, potassium, and zinc in comparison to other nutrient sources and the lowest were found under control plots. The possible reason behind this is the rapid mineralization of potassium, phosphorus and zinc at higher levels of organic matter and the accumulation of higher organic carbon in soil affects phosphorus, potassium and zinc content. Chemical properties such as soil organic carbon, soil microbial biomass carbon, dehydrogenase enzyme activity, available N and K in soil were recorded higher in treatments applied with organic nutrients[20,21].

Soil microbiological studies

The inclusion of FYM, vermicompost and other cow-based nutrient formulations increased soil quality by improving the rhizosphere microbial community as well as wheat crop grain production (Table 7, 8 & 9). Soil microbes population viz., total bacteria, fungi, Azotobacter count, phosphorus solubilizers bacteria count and potassium solubilizers bacteria count in the soil is recorded at 30 days interval up to the harvest of the wheat crop.

Total bacteria count (CFU x 10^6 per g dry soil)

From sowing to 90 DAS, the bacterial population increases, then declines before the seed is harvested, regardless of nutrient source. At all stages of the wheat crop, the maximum bacterial population was registered under T_2 (3.71, 4.51, 5.77, 3.85 and 2.54 at 30, 60, 90, 120 DAS and harvest, respectively), which

Table 6 — Effect of nutrient sources on soil properties after the harvest of wheat

Treatment	pH	EC (dS/m)	Organic carbon (g/kg)	Available Nitrogen (kg/ha)	Available Phosphorous (kg/ha)	Available Potassium (kg/ha)	Available Zinc (kg/ha)
T_1	7.7	0.38	3.0	127.6	15.6	255.3	1.56
T_2	7.6	0.37	3.1	128.8	16.9	253.8	1.58
T_3	7.7	0.37	2.9	120.7	14.4	248.6	1.52
T_4	7.7	0.36	2.9	121.8	14.6	248.9	1.52
T_5	7.8	0.36	2.9	122.4	14.9	249.4	1.54
T_6	7.9	0.37	2.9	123.6	15.1	249.9	1.54
T_7	7.4	0.37	2.8	125.4	15.7	254.3	1.56
T_8	7.5	0.37	2.9	118.5	14.2	247.7	1.48
SEm ±	0.17	0.01	0.13	1.82	0.17	2.51	0.04
CD (p=0.05)	NS	NS	NS	5.52	0.53	7.61	NS

Table 7 — Effect of nutrient sources in the wheat crop on total soil bacterial population and total soil fungi population

Treatment	Total Bacterial population (CFU x 10^6 per g dry soil)					Total Fungi population (CFU x 10^4 per g dry soil)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	3.52	4.45	5.70	3.74	2.43	11.34	18.29	22.50	19.12	16.83
T_2	3.71	4.51	5.77	3.85	2.54	11.87	18.54	22.80	19.38	17.06
T_3	1.98	2.54	3.25	2.61	1.92	10.58	16.52	20.32	17.27	15.20
T_4	2.01	2.63	3.37	2.65	1.98	10.61	16.72	20.57	17.48	15.38
T_5	2.11	2.69	3.44	2.78	2.04	10.64	16.77	20.63	17.53	15.43
T_6	2.16	2.71	3.47	2.81	2.13	10.78	16.89	20.77	17.66	15.54
T_7	1.87	2.18	2.79	1.87	1.21	7.94	10.84	13.33	11.33	9.97
T_8	1.71	1.98	2.53	1.61	1.08	7.46	8.39	10.32	8.77	7.72
SEm ±	0.04	0.5	0.6	0.4	0.3	0.13	0.20	0.25	0.22	0.17
CD (p=0.05)	0.12	0.16	0.19	0.13	0.08	0.40	0.60	0.76	0.67	0.52

Table 8 — Effect of nutrient sources in the wheat crop on soil *Azotobacter* population and soil fungi phosphorus solubilizers bacteria

Treatment	*Azotobacter* population (CFU x 10^5 per g dry soil)					Phosphorus solubilizers bacteria (PSB) (CFU x 10^5 per gm dry soil)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	12.21	16.48	23.90	20.08	13.65	8.79	11.6	17.52	14.72	10.45
T_2	12.67	17.10	24.80	20.83	14.17	9.27	12.24	18.48	15.52	11.02
T_3	10.08	13.61	19.73	16.57	11.27	7.07	9.33	14.09	11.84	8.41
T_4	10.29	13.89	20.14	16.92	11.51	7.27	9.6	14.49	12.17	8.64
T_5	10.54	14.23	20.63	17.33	11.79	7.39	9.75	14.73	12.37	8.78
T_6	10.86	14.66	21.26	17.86	12.14	7.85	10.36	15.65	13.14	9.33
T_7	9.89	13.35	19.36	16.26	11.06	6.35	8.38	12.66	10.63	7.55
T_8	9.34	12.61	18.28	15.36	10.44	6.02	7.95	12	10.08	7.16
SEm ±	0.15	0.21	0.24	0.23	0.16	0.1	0.14	0.22	0.16	0.11
CD (p=0.05)	0.12	0.16	0.19	0.13	0.08	0.40	0.60	0.76	0.67	0.52

Table 9 — Effect of nutrient sources on soil potassium solubilizers (Potassium solubilizing bacteria, KSB) and yield of the wheat crop

Treatment	Potassium solubilizing bacteria (KSB) (CFU x 10^5 per g dry soil)				
	30 DAS	60 DAS	90 DAS	120 DAS	At harvest
T_1	5.89	8.36	12.63	9.98	6.68
T_2	5.41	7.68	11.60	9.16	6.14
T_3	3.54	5.03	7.59	6.00	4.02
T_4	3.78	5.37	8.11	6.40	4.29
T_5	3.81	5.41	8.17	6.45	4.32
T_6	3.92	5.57	8.41	6.64	4.45
T_7	2.86	4.06	6.13	4.84	3.25
T_8	2.24	3.18	4.80	3.79	2.54
SEm ±	0.05	0.08	0.12	0.08	0.06
CD (p=0.05)	0.16	0.24	0.37	0.25	0.17

was substantially higher than other nutrient sources. At 90 DAS, the highest bacterial count was reported under T_2 (5.77), which was statistically comparable to T_1 and substantially higher than the other treatments. The least count was recorded under control (2.53) at 90 DAS. Application of cow-based organic formulations, jivamrit and combined application of jivamrit, ghanjivamrit and saptdhanya ankur ark had no significant effect in terms of bacterial population and treatment T_3, T_4, $T_5$and T_6 were statistically at par with each other at different growth stages of wheat crop.

Total fungi count (CFU x 10^6 per g dry soil)

The fungi population grew as the wheat crop progressed up to 90 DAS and then began to decline before the wheat crop was harvested. Various nutrient sources had a significant effect on fungi count at different growth phases of wheat crop. T_2 recorded the highest fungi count (11.87, 18.54, 22.80, 19.38 and 17.06at 30 days intervals up to the harvest of crop, respectively), which was statistically at par with T_1 at all stages of wheat crop and significantly higher than other treatments. At 90 DAS maximum fungi count was recorded in the respective treatments and the highest was recorded in T_2 (22.80) followed by T_1 (22.50) and T_6 (20.77), whereas the lowest fungi count was reported under control (10.32). Cow based nutrient treatments T_3, T_4, T_5 and T_6 were statistically at par with each other at all the stages of the wheat crop in terms of fungi population. However, the lowest fungi count was observed under controlled conditions at all the observations followed by T_7.

Diazotrophic: Azotobacter count (CFU x 10^4 per g dry soil)

The population of *Azotobacter* increases throughout the various growth stages of the crop and reached the highest count at 90 DAS under all the treatments and declined until the harvest of the wheat crop. T_2 recorded the highest population of *Azotobacter* (12.67, 17.10, 24.80, 20.83, and 14.17 at 30, 60, 90, 120 DAS and at harvest, respectively) which was significantly superior over the other treatments. At 90 DAS highest Azotobacter count in soil was recorded under T_2 (24.80) followed by T_1 (23.90), T_6 (21.26), whereas the lowest *Azotobacter* count was observed under control (18.28). T_3, T_4 and, T_5 were statistically at par with each other at all stages of observations, while T_6, which was significantly superior over these treatments at all recorded observations.

Phosphorus solubilizers: Phosphorus solubilizing bacteria, PSB count (CFU x 10^5 per g dry soil)

After the sowing of wheat, the PSB population increases up to 90 DAS and then starts decreasing till the harvest of the wheat crop. The highest population of phosphorus solubilizing bacteria was found in T_2 (9.27, 12.24, 18.48, 15.52, and 11.02 at 30 days intervals from sowing to the harvest of the wheat crop, respectively) followed by T_1 which was statistically significant from T_2 at all the recorded observations. The maximum population of PSB was recorded at 90 DAS. Among cow-based nutrient sources, T_6 observed the highest PSB count (7.85, 10.36, 15.65, 13.14 and 9.33 at 30 days intervals from sowing to the harvest of the wheat crop, respectively) which was significantly superior to T_3, T_4 and T_5. However, the lowest Phosphorus solubilizing bacteria were found under control followed by T_7 at all the recorded observations from 30 DAS till the harvest of the wheat crop.

Potassium solubilizers: Potassium solubilizing bacteria, KSB count (CFU x 10^5 per g dry soil)

With the advancement of the wheat crop population of KSB increases after the sowing of crop up to 90 DAS and then the KSB count declined up to the harvest of the wheat crop, showing a maximum count at 90 DAS. T_1shows the highest KSB count (5.89, 8.36, 12.63, 9.98, and 6.68 at 30 days intervals from sowing to the harvest of the wheat crop, respectively) which was significantly superior over all the other treatments. The second highest KSB count was recorded with the application of T_2 followed by T_6, T_5, T_4, T_3, T_7, and the lowest KSB population was found under control at all the stages of observations.

The microbiological properties of soil were enhanced by using organic manures as a source of nutrients. The change in microbial properties and count in soil may be explained by an increase in organic carbon in the soil caused by different organic manures. Available organic carbon in soil is used as a source of food by various micro-fauna in soil and provides more energy to them, which ultimately increases microbial activity and count in the soil rhizosphere. Because of crop uptake, nutrients were depleted after 90 DAS, causing the microbial community to decrease at later stages[22]. The highest microbial population was observed when nutrients were applied through FYM or vermicompost[23]. Treatments applied with organic sources of nutrients recorded higher bacterial, fungal, P-solubilizers and soil alkaline phosphatase activity as compared to control and synthetic applied fertilizers[24,25].

The count of azotobacter and phosphorus solubilizing bacteria (PSB) increases as different organic sources of nutrients are applied; this may be attributed due to the positive effects of favourable nutrients supply and improved soil quality by changing soil physico-chemical and microbiological properties. The application of organic matter and organic nutrient sources may have developed a favorable environment for the formation of humic acid, organic carbon, which acts as food for microbes and ultimately increase their activity in the soil. The secretion of metabolites from wheat root exudates contains organic compounds, which act as a nutrition sou rce for microbes and further increases their colony-forming process of azotobacter, phosphorus solubilizer bacteria[26].

Conclusion

It was concluded that the addition of organic manures in the form of FYM, vermicompost and other cow-based nutrient formulations have improved soil health by increasing nutrient status and organic matter in the soil. Organic nutrient supplies enhanced the physical, chemical and biological properties of the rhizosphere, which enhanced the crop's economic output. Based on the findings of this research, it can be suggested that the combined use of both organic and synthetic fertilizers as a source of nutrition gave optimum productivity and improved soil health. Organic sources of nutrients can be a good substitute or complement to inorganic synthetic fertilizer in producing optimum yield and maintaining soil health in organically cultivated soils for an eco-friendly agricultural environment by boosting microbial activities.

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Conflict of Interest

The authors declare that they have no conflict of interest financial or otherwise.

Authors' Contributions

DL & SK: Conceptualization, Experimentation, Formal analysis, Original draft; PK: Statistical Analysis & Interpretation of data; S, AD, I, SB & A: Review & Editing of Manuscript.

References

1 Anonymous, Area, production and productivity of wheat crop in India, Directorate of Economics and Statistics, Ministry of Agriculture, https://www.indiastat.com/data/agriculture/wheat-17195/data-year/2018 (2020) 85-136.

2 Charyulu D K & Biswas S, Organic input production and marketing in India-efficiency, issues and policies, Centre for Management in Agriculture, Indian Institute of Management, Ahmedabad, 239 (2010).

3 Meena R K, Singh Y V, Nath C P, Bana R S & Lal B, Importance, prospects and constraints of organic farming in India, *Popular Kheti*, 1 (4) (2013) 26-31.

4 Prasad R, Rice-wheat cropping system, *Adv Agron*, 86 (2005) 255-339.

5 Lodhi A, Sajjad M H, Mahmood A & Azam F, Response of wheat (*Triticum aestivum* L.) to organic amendment and application of urea, *J Soil Sci Environ*, 25 (2) (2006) 99-104.

6 Willer H & Yussefi M, The world of organic agriculture statistics and emerging trends, International Federation of Organic Agriculture Movements, Bonn, Germany (2005).

7 Korsaeth A, Henriksen T M & Bakken L R, Temporal changes in mineralization and immobilization of N during degradation of plant material: implications for the plant N supply and nitrogen losses, *Soil Biol Biochem*, 34 (6) (2002) 789-799.

8 Ersahin Y S, The use of vermicompost products to control plant diseases and pests, In: Biology of earthworms, *Soil Biol*, (2011) 191-213.

9 Jain S, Khaddar V K, Chaudhary S K & Phadnis S, Effect of organics and chemical fertilizer on growth, yield attributes and yield of the soybean-wheat cropping sequence, *Res Crop*, 5 (1) (2004) 22-30.

10 Lazarovits G, Rhizobacteria for improvement of plant growth and establishment, *J Hortic Sci*, 32 (1997) 188-192.

11 Jain D, Jain P, Bhojiya A A, Jain R K, Choudhary R, *et al*., Microbiological and enzymatic properties of diverse Jaivik Krishi inputs used in organic farming, *Indian J Tradit Know*, 20 (1) (2021) 237-243.

12 Bodapti S & Chander M, Integrating indigenous knowledge of farmers for sustainable organic farming: An assessment in Uttarakhand state of India, *Indian J Tradit Know*, 12 (2) (2013) 259-264.

13 Sheoran O P, Tonk D S, Kaushik L S, Hasija R C & Pannu R S, Statistical software package for agricultural research workers, Recent advances in information theory- statistics & computer applications, (1998) 139-143.

14 MacRae R J, Hill S B & Mehuys G R, Farm-scale agronomic and economic conversion from conventional to sustainable agriculture, *Adv Agron*, 43 (1993) 155-198.

15 Hadis M, Meteke G & Haile W, Response of bread wheat to the integrated application of vermicompost and NPK fertilizers, *Afr J Agric Res*, 13 (1) (2018) 14-20.

16 Ibrahim M, Hassan A, Iqbal M & Valeem E E, Response of wheat growth and yield to various levels of compost and organic manure, *Pak J Bot*, 40 (5) (2008) 2135-2141.

17 Yousefi A A & Sadeghi M, Effect of vermicompost and urea chemical fertilizers on yield and yield components of wheat (*Triticum aestivum* L.) in the field condition, *Int J Agric Crop Sci*, 7 (12) (2014) 1227- 1230.

18 Upadhyay V B, Jain V, Vishwakarma S K & Kumar A K, Production potential, soil health water productivity, and economics of rice (*Oryza sativa*) based cropping system under different nutrients sources, *Indian J Agron*, 56 (4) (2011) 311-316.

19 Devi K N, Singh M S, Singh N G & Thokpam S A, Effect of integrated nutrient management on growth and yield of wheat (*Triticum aestivum* L.), *J Crop Weed*, 7 (2) (2011) 23-27.

20 Saini J P & Kumar R, Long term effect of organic sources of nutrients on productivity and soil health in maize+soybean-wheat+gram cropping system, *J Org Bridge*, 2 (2014) 611-614.

21 Kumar B, Gupta R K & Bhandari A L, Soil fertility changes after long-term application of organic manures and crop residues under the rice-wheat system, *J Indian Soc Soil Sci*, 56 (1) (2008) 80-85.

22 Sah A K, Singh M, Pradhan A K, Prasad S, Chatoopadhyaya N, *et al*., Effect of organic fertilizer and microbial inoculants on soil biological properties and yield of scented rice (*Oryza sativa* L.), *J Appl Nat Sci*, 10 (3) (2018) 995-1002.

23 Meena B P, Kumar A, Lal B, Sinha N K, Tiwari P K, *et al*., Soil microbial, chemical properties and crop productivity as affected by organic manure application in popcorn (*Zea mays* L. *var. everta)*, *Afr J Microbiol Res*, 9 (21) (2015) 1402-1408.

24 Brar A Gosal S K & Walia S S, Effect of biofertilizers and farm yard manure on microbial dynamics and soil health in maize (*Zea mays* L.) rhizosphere, *Chem Sci Rev Lett*, 6 (23) (2017) 1524-1529.

25 Kumar P, Yadava R K, Gollen B, Kumar S, Verma R K, *et al*., Nutritional content and medicinal properties of wheat: a review, *Life Sci Med Res*, 22 (2011) 1-10.

26 Iswandi A O P, Rupela T M & Thiyagarajan, A review of studies on SRI effects on beneficial organisms in rice soil rhizospheres, *Paddy Water Environ*, 9 (2011) 53-64.

27 Piper C S, *Soil and Plant Analysis*, *Hans Publishers*, Bombay (1966).

28 Jackson M L, Soil chemical analysis, *Prentice Hall of India Pvt. Ltd.* New Delhi, (1973) 468.

29 Richards L A, Diagnosis and improvement of saline and alkali soils, USDA, The United States Salinity Laboratory Staff, Hand Book No. 60 (1954).

30 Subbiah B C & Asija G L, A rapid procedure for the estimation of available nitrogen in soils, *Curr Sci*, 25 (1956) 259-60.

31 Olsen S R, Cole C V, Watanable F S & Dean L A, Estimation of available phosphorous in soil extraction with sodium bicarbonate, *USDA Circular*, (1954) 939.

32 Lindsay W L & Norwell W A, Development of a DTPA soil test for zinc, iron, manganese and copper, *Soil Sci Soc Am J*, 42 (3) (1978) 421-428.