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Changes in Physico-chemical and chemical characteristics of soil due to adoption of natural farming practices in wheat- mustard cropping systems

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Abstract
A field experiment was carried out at the Instructional cum Research Farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (C.G.) where three nutrient management systems were compared on wheat-mustard during 2020-21 & 2021-22 in an Vertisols to evaluate the effect of different combinations of natural, organic farming and integrated crop management system on soil properties and crop yield. The experiment consisted of 9 treatments *viz.* (T_1) Control (No addition of any inputs except labour for operation including weeding), (T_2) Complete Natural Farming (I. Beejamrit + Ghanjeevamrit + Jeevamrit II. Crop residue mulching III. Intercropping IV. Whapasa), (T_3) Natural Farming-1 (without Beejamrit + Ghanjeevamrit + Jeevamrit), (T_4) Natural Farming-2 (Without crop residue/ Mulching), (T_5) Natural Farming-3 (Without Intercropping), (T_6) Natural Farming-4 (Without Whapasa), (T_7) Organic farming practices as per AI-NPOF Package (75% RDN through organic sources + 10% foliar spray of vermiwash and cow urine at 30 and 50 DAS), (T_8) Integrated crop management (50% RDN through organic sources and 50% RDN through inorganic nutrient sources with application of Neemastra, Agniastra, Bramhastra and Dasparni ark for pest management), and (T_9) Integrated crop management (50% RDN through organic sources and 50% RDN through inorganic nutrient sources with application of need based inorganic pesticide for the control of pest management). The aim of using different combinations of nutrient management systems is to find out best combination which can supplement nutrients to fulfill the nutrient requirement of crop.

In case of wheat-mustard cropping system the pH of soil reached to 6.96 in organic farming practices, followed by 6.95 in complete natural farming. In case of EC 0.27 dS m^{-1} was recorded in organic farming practices, followed by 0.26 in complete natural farming. The highest organic carbon content (0.70%) were observed in organic farming practices, followed by complete natural farming where values were recorded as (0.68%). The observation on soil residual nutrients revealed that in both the cropping system the highest soil available nitrogen, phosphorus and potash were attributed with integrated crop management practice using organic pest control. In wheat - mustard cropping system the values were 157.74 kg/ha, 19.20 kg/ha, 386.05 kg/ha for nitrogen, phosphorus and potash was observed in integrated crop management practice using organic pest control. Highest wheat seed yield (3492.21 kg ha^{-1}) was recorded in organic farming package, followed by integrated crop management system using organic pest control (3438.71 kg ha^{-1}). The maize were grown only under natural farming with different combination of inputs. However, the highest mustard seed yield (377.87 kg ha^{-1}) was recorded in complete natural farming package, followed by natural farming (NF) - (without whapasa) (348.47 kg ha^{-1}).

The results of the investigation revealed that the organic farming practices as per All India Network Project on Organic Farming package (75% RDN through organic sources + 10% foliar spray of vermi wash and cow urine at 30 and 50 DAS) was found most effective to improve the physico-chemical, chemical, microbial and biochemical properties of soil and crop yield, followed by complete natural farming (I. Beejamrit + Ghanjeevamrit + Jeevamrit, II. Crop residue mulching, III. Intercropping and IV.Whapasa).

Keywords: Soil pH, soil EC, Available NPK, organic carbon content, grain yield

Introduction
According to FAO, by 2050 the world needs to increase overall food production by 70 per cent in order to keep up with the growing global population and the changes in consumption driven

by expanding middle class. At the same time India is expected to be the most populous country in the world by 2030, with 1.51 billion people (FAO, 2017) [13]. Under such condition, ensuring food security for the population would be one of the biggest concerns for the country. Therefore, adopting Large-scale agricultural techniques or production technologies that lack scientific backing, could negatively impact crop productivity, or both could raise severe questions for the country's aim of guaranteeing food and nutrition security.

'Green Revolution' The country's food deficit was alleviated in part by the adoption of technologies in the middle of the 1960s, including irrigation, chemical fertilizer, and extensive usage of HYV seeds. However, there have been significant negative effects of agriculture intensification on the environment, such as soil degradation, eutrophication of land and water bodies, emissions of greenhouse gases (GHGs), and losses in biodiversity (Evenson and Gollin, 2003; Canfield *et al*., 2010) [11, 7]. In contrast, Natural Farming (NF) is a distinct chemical-free farming technique that integrates crops, trees, and livestock in a varied farming system based on agro ecology, allowing for functional biodiversity (Rosset and Martinez-Torres, 2012) [30]. Similarly organic farming has several advantages over farming by inorganic fertilizers like organic manures produce optimal condition in the soil for high yields and good quality crops. They supply the entire nutrient required by the plant (primary, secondary and micronutrients), improve plant growth and physiological activities of plants, soil physical properties such as granulation and good tilt, good aeration, easy root penetration and improved water holding capacity. Organic manures improve the soil chemical properties such as supply and retention of soil nutrients and promote favorable chemical reaction. They reduce the need for purchased inputs.

The prolonged application of chemical fertilizers alone leads to deterioration of soil productivity and fertility, reduced agricultural productivity, the main reasons to consider replacing the nutrients that crops require with different inputs are rising production costs, a heavy reliance on non-renewable resources, a reduction in microbial diversity, water contamination, chemical residues in food grains, and public health risks (Aher *et al.*, 2012) [2]. Organic sources of nutrients improve the availability and quality of food while providing a special blend of ecologically friendly methods with minimal outside inputs.

The growing concerns about the ill effects of chemical fertilizers emphasize a need for change in agricultural production technologies through an appropriate sustainable, eco-friendly approach. Worldwide the concept of organic farming was started with the objective of providing safe and quality produce just few decades back. However, some of the burning issues like availability of large quantity of organic manures to meet out the nutrient requirement, diseases and insect-pests problems, weeds and low yields during the initial years of conversion, etc. are imposing setback for adoption of organic farming at a large scale. Zero Budget Natural Farming (ZBNF) is an additional farming approach that Padam Shri Dr. Subhash Palekar has suggested. This is a new concept introduced with an aim of sustainable development. It replaces use of farm yard manure and compost from organic farming with cover crops, green manure crops and use of preparations made from desi cow. With the help of these, humus formation takes places within field as compared to organic farming in which humus formation takes place at the site of farm yard manure and compost preparation. Humus is a rich source of nutrients where in nutrients are released slowly and leads to better uptake by plants. Zero budget Natural Farming is a low-input, climate-resilient type of farming that encourages farmers to use low cost locally-sourced inputs, eliminating the use of artificial fertilizers, and industrial pesticides.

According to Food and Agriculture Organization (FAO, 2002) [12], integrated crop management (ICM) has been adopted recently in agriculture and is of much significance and relevance than the individual approach of energy management, weeds, diseases, pests, crop, soil, water, and nutrients (Varatharajan *et al.* 2019). Therefore, integrated crop management, or ICM, is a comprehensive and site-specific approach to sustainable agriculture that considers every aspects of farm productivity, including environmental, socioeconomic, and on-farm resources to provide the safest and most appropriate strategy for long-term gains (Choudhary *et al.*, 2018) [10].

Wheat (*Triticum aestivum* L.) is a native of Turkey belonging to Poaceae family. It is known to India since prehistoric time. Around the world, wheat is grown in a variety of conditions. Soybean followed by wheat cropping system under variable sowing windows results higher productivity and uptake of nutrients of soybean-wheat cropping system (Nawale *et al*., 2018) [24].

Natural farming saw enormous rise with several state adoption as state policy or grass root movement in southern states. With adoption as state policies of several state government to move towards organic farming it needs scientific validation in terms of its impacts on productivity in different agro climatic conditions, different cropping systems and different soil types. Utilizing natural farming methods and cereal-legume intercropping together can be the best ways to lower greenhouse gas emissions, stabilize yields, and preserve soil fertility. Keeping these in mind the present study was conducted to examine natural farming in terms of soil health research.

Keeping this in view, in this study wheat - mustard crop will be grown in *rabi* season which normally grown as inter crops. The present study is planned to find out the best system which will give maximum crop productivity, its sustainability and keep the soil healthy

Materials and Methods

The present investigation was conducted in instructional cum research farm of Indira Gandhi Krishi Vishwavidyalaya, Raipur where three different combination of nutrient management systems were compared by using randomized block design (RBD). Different combinations of nutrient management were, (T_1) Control (No addition of any inputs except labour for operation including weeding), (T_2) Complete Natural Farming (Ⅰ. Beejamrit+Ghanjeevamrit+jeevamrit Ⅱ. Crop residue mulching Ⅲ. Intercropping Ⅳ.Whapasa), (T_3) Natural Farming-1 (Without Beejamrit+Ghanjeevamrit+jeevamrit), (T_4) Natural Farming-2 (Without Crop residue/ Mulching), (T_5) Natural Farming-3 (Without Intercropping), (T_6) Natural Farming-4 (Without Whapasa), (T_7) Organic farming practices as per AI-NPOF Package (75% RDN through organic sources + 10% foliar spray of vermiwash and cow urine at 30 and 50 DAS), (T_8) Integrated crop management (50% RDN through organic sources and 50% RDN through inorganic nutrient sources with application of Neemastra, Agniastra, Bramhastra and Dasparni ark for pest management), and (T_9) Integrated crop management (50% RDN through organic sources and 50% RDN through inorganic nutrient sources with application of need based inorganic pesticide for the control of pest management). Which were applied in treatment plots sampling of soil was done from different experimental plots carrying different treatments and analyzed for physico-chemical and chemical properties at different growth stages of crops. The crop yield was also recorded at harvest.

Soil samples from field were collected from 7.5-15cm from the soil surface at different stages of crop growth. The pooled soil samples were subjected to analysis for soil physico-chemical and chemical analysis. A 10 g air dried soil was taken in a clean 50 ml. beaker and 25 ml. of distilled water was added to it. The suspension was stirred intermittent for 30 minutes. The pH of soil water suspension was recorded using pH meter (Piper, 1967) [28]. The EC was determined by Conductivity Bridge as described by Jackson (1973). For this determination 10 g of soil was weighed and taken in a 50 ml. beaker, 25 ml. distilled water was added and suspension was stirred intermittently for 30 minutes and allowed the suspension to settle for about one hour. The measure of EC in supernatant solution was done by using EC Bridge. Organic carbon content in soil was determined by the rapid dichromate oxidation technique given by Schollenberber *et al*. (1927) [31]. One g air dried soil sample was taken in dry 500 ml conical flask and added 10 ml of 1N $K_2Cr_2O_7$ with the help of volumetric pipette and swirled a little. To this 20 ml of H_2SO_4 was then added and swirl again 2-3 times and kept the flask on an asbestos sheet for 30 min. Then 200 ml of distilled water, 10 ml of H_3PO_4, 0.5 gm Sodium Fluoride and 1 ml Diphenylamine indicator were added. Titrated the content against 0.5N Fe $(NH_4)_2$ $(SO_4)_2$ till the colour flashed from blue-violet to green. Crop yield was recorded at harvest of the crop. Before and after harvest of crop soil analysis was done for quantification of available NPK. In this regard available N was determined by alkaline $KMnO_4$ method of Subbiah and Asija (1965), Soil phosphorus was extracted by 0.5M $NaHCO_3$ as described by Olsen *et al*. (1954) [25], Potassium was estimated by flame photometer (Muhr *et al*., 1965) [23]. All the pre and post-harvest observations were recorded and tabulated in a systematic manner. The final observations were statistically analyzed by randomized block design (RBD).

Treatment details

T_1	Control (No addition of any inputs except labour for operation including weeding)
T_2	Complete Natural Farming (1.Beejamrit+ Ghanjeevamrit+ Jeevamrit 2. Crop residue Mulching 3.Intercropping 4. Whapasa)
T_3	Natural Farming-1 (Without Beejamrit+ Ghanjeevamrit + Jeevamrit)
T_4	Natural Farming-2 (Without Crop residue/ Mulching)
T_5	Natural Farming-3 (Without Intercropping)
T_6	Natural Farming-4 (Without Whapasa)
T_7	All India Network Programme on Organic Farming (AI-NPOF) Package (75% RDN through organic sources + 10% foliar spray vermiwash and cow urine at 30 and 50 DAS)
T_8	Integrated Crop Management (50% RDN through organic sources and 50% RDN through inorganic nutrient sources with application of Neemastra, Agniastra, Bramhastra and Dasparni ark for pest management).
T_9	Integrated Crop Management (50% RDN through organic sources and 50% RDN through inorganic nutrient sources with application of need based pesticide for pest management.

Results and Discussion

Physico-chemical analysis

Soil pH: The data pertaining to soil pH of wheat and mustard crop at initial and at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section. After the completion of experiment the pH of all the treatments remained in acidic spectrum are presented in Table 1. The finding revealed that different treatments of wheat and mustard crop did not affect the soil pH significantly before and after conduction of experiments in both the years on mean basis. Almost no differences were observed in soil pH in 2020-21, as this is the year of initialization of experiment. Hence we can hypothesized that soil pH is uniform throughout the experimental field. However in 2nd year of experimentation a non-significant change in soil pH was observed among treatments. In 2nd year (2021-22), the initial highest soil pH (6.95) was observed in organic farming practice, followed by complete natural farming (6.94) and integrated crop management (6.93) using organic pest control and minimum soil pH was observed in control treatment (6.86).

At harvest stage highest soil pH (6.96) was observed in organic farming practice followed by complete natural farming (6.95) and integrated crop management (6.94) using organic pest control. Minimum soil pH was observed in control treatment (6.87). The variation in soil pH before and after the experimentation was found 0.02 that was due to the conduction of experimentation. The increment was found uniform across the treatment. The enhancement of pH value under different treatments might be due release of different salts which acts buffering agent to enhance the soil pH towards neutrality. Similar results have also been reported Pathak *et al.* (2007) [27] and Sharma *et al.* (2007) [33] also reported the moderating effect of FYM and vermi compost on soil pH, as registered in the present study found that organic farming package recorded maximum pH was found at initial and harvest stage of crop growth compared to control treatment, probably due to complexing of exchangeable and free Al-ion by aliphatic and aromatic hydroxyl acids produced during decomposition.

Table 1: Soil pH at initial and harvest of wheat as influenced by different natural, organic farming and integrated crop management practices

	pH (initial)			pH (harvest)			Increase/Decrease
	2020	2021	Mean	2020	2021	Mean	pH
T_1	6.84	6.86	6.85	6.85	6.89	6.87	+ 0.02
T_2	6.92	6.94	6.93	6.93	6.97	6.95	+ 0.02
T_3	6.96	6.83	6.89	6.97	6.86	6.91	+ 0.02
T_4	6.86	6.88	6.87	6.87	6.91	6.89	+ 0.02
T_5	6.85	6.87	6.86	6.86	6.90	6.88	+ 0.02
T_6	6.88	6.92	6.90	6.89	6.95	6.92	+ 0.02
T_7	6.93	6.95	6.94	6.94	6.98	6.96	+ 0.02
T_8	6.91	6.93	6.92	6.92	6.96	6.94	+ 0.02
T_9	6.92	6.90	6.91	6.93	6.93	6.93	+ 0.02
S.E.M±	0.20	0.20	0.20	0.20	0.20	0.20	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	

T_1: Control, T_2: Complete Natural Farming package (NF), T_3: NF- (Without Beejamrit+Ghanjeevamrit+jeevamrit), T_4: NF-(Without crop residue mulching), T_5: NF-(Without intercropping), T_6: NF-(Without whapasa), T7: AI-NPOF package (organic farming practices), T_8: Integrated Crop Management (Organic pest control), T_9: Integrated Crop Management (Inorganic pest control).

Soil Electrical Conductivity (dS m^{-1})

The data pertaining to soil electrical conductivity (EC) (dS m^{-1}) of wheat and mustard crop at initial, and at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section and are presented in Table 2.

The findings revealed that different treatments applied to soybean and maize crop did not affect the soil EC significantly before and after conduction of experiments in both the years on mean basis. Almost no differences were observed in soil EC in 2020, as this the year of initialization of experiment. Hence we can hypothesized that soil EC is uniform throughout the experimental field. However in 2nd year of experimentation a non-significant change in soil pH was observed among treatments. In 2nd year (2021), the initial highest soil EC (0.26 dS m^{-1}) was observed in organic farming practice, followed by complete natural farming (0.25) and integrated crop management (0.24) using organic pest control. Minimum soil EC was observed in control treatment (0.18).

At harvest stage highest soil EC (0.27 dS m^{-1}) was observed in organic farming practice followed by complete natural farming (0.26) and integrated crop management (0.25) using organic pest control, Minimum soil EC was observed in control treatment (0.19). The variation in soil EC before and after the experimentation was found 0.02 that was due to the conduction of experimentation. The increment was found uniform across the treatments. Slight increase of EC in organic farming practices might be due to addition of organic inputs (FYM and vermi compost), that resulted increase of salt concentration in soil as compared to control treatment. Higher EC under different treatments comprising organic manures and nutrient management might be due release of different salts. These finding were in close conformity with similar results were found by Gore and Sreenivasa (2011) [14], Shaikh and Gachande (2016) [32] who found that EC values of the soil were not significantly influenced by organic manures and nutrient management either alone or in combination at different levels of nutrients.

Table 2: Soil EC at initial and harvest of wheat as influenced by different natural, organic farming and integrated crop management practices.

	EC (dS m^{-1}) (initial)			EC (dS m^{-1}) (harvest)			Increase/Decrease
	2020	2021	Mean	2020	2021	Mean	EC
T_1	0.17	0.18	0.17	0.18	0.20	0.19	+ 0.02
T_2	0.24	0.25	0.24	0.25	0.27	0.26	+ 0.02
T_3	0.20	0.21	0.20	0.21	0.23	0.22	+ 0.02
T_4	0.19	0.20	0.19	0.20	0.22	0.21	+ 0.02
T_5	0.18	0.19	0.18	0.19	0.21	0.20	+ 0.02
T_6	0.21	0.22	0.21	0.22	0.24	0.21	+ 0.02
T_7	0.25	0.26	0.25	0.26	0.28	0.27	+ 0.02
T_8	0.23	0.24	0.23	0.24	0.26	0.25	+ 0.02
T_9	0.22	0.23	0.22	0.23	0.25	0.24	+ 0.02
S.E.M±	0.006	0.006	0.006	0.006	0.006	0.006	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	

T_1: Control, T_2: Complete Natural Farming package (NF), T_3: NF-(Without Beejamrit+Ghanjeevamrit+jeevamrit), T_4: NF-(Without crop residue mulching), T_5: NF-(Without intercropping), T6: NF-(Without whapasa), T^7: AI-NPOF package (organic farming practices), T_8: Integrated Crop Management (Organic pest control), T_9: Integrated Crop Management (Inorganic pest control).

Soil organic carbon content (%)

The data pertaining to soil organic carbon content (%) in wheat and mustard cropping system quantified at 0, 30, 60 DAS and at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section are presented in Fig. 1.

The findings revealed that different treatments applied to wheat and mustard crop significantly affected the soil organic carbon at 30, 60 DAS and at harvest due to conduction of experiments in both the years on mean basis. In 2nd year (2021-22), the initial highest soil organic carbon content was observed under organic farming package (0.60%) followed by complete natural farming practice (NF) (0.59%). Minimum was found under control treatment (0.52%). However, all the treatments were found at par among each other.

At 30 DAS maximum soil organic carbon content was observed under organic farming practice (0.62%) followed by complete natural farming package (NF) (0.61%), Minimum was found under control treatment (0.54%).

At 60 DAS maximum soil organic carbon content was observed under organic farming practice (0.64%), followed by complete natural farming package (NF) (0.63%) and minimum was found under control treatment (0.55%). The organic carbon content quantified in organic farming practice found significantly superior over natural farming practice.

At harvest highest soil organic carbon content was observed under organic farming practice (0.70%) followed by complete natural farming package (NF) (0.68%), Minimum was found under control treatment (0.55%). The data on soil organic carbon (%) as influenced by different treatments have indicated slightly higher values of organic carbon content after harvest of the crop during both the years of experiment. Maximum organic carbon accumulation (0.08%) was found in organic farming system, followed by complete natural farming package where (0.07%) organic carbon increased in soil. In this study we found a gradual increase in soil organic carbon from 60 DAS onwards up to harvest due to adoption of different treatments. Organic nutrients (manures and root biomass) have the largest effect in soil organic carbon (Khaleel *et al*., 1981; Badanur *et al*., 1990) [18, 4]. Tiwari *et al*. (2002) [38] and Kaur *et al*. (2005) [17] reported increased soil organic carbon in organic farming system compared to chemical farming practice. The soil organic carbon was greater in organic and integrated farming practices, which attributed to more carbon going to soil via organic manure addition. Manna *et al.* (2007) [22]; Ramesh *et al.* (2009) [29] and Panwar *et al.* (2010) [26] reported higher soil organic carbon in the treatments receiving organic nutrients over a long term period. Chang *et al.* (2014) [8] suggested organic amendment for improving soil organic carbon. The level of organic matter tends to be enhanced in soils amended with organic nutrient (manure and straw). Significant increase in organic carbon due to application of FYM might be attributed to excessive microbial activity of soil. Manjunath *et al.* (2012) [21] and Sharma and Prasad (2002) [34] also reported a significant increase in soil organic carbon in wheat cropping system due to addition of FYM and crop residues.

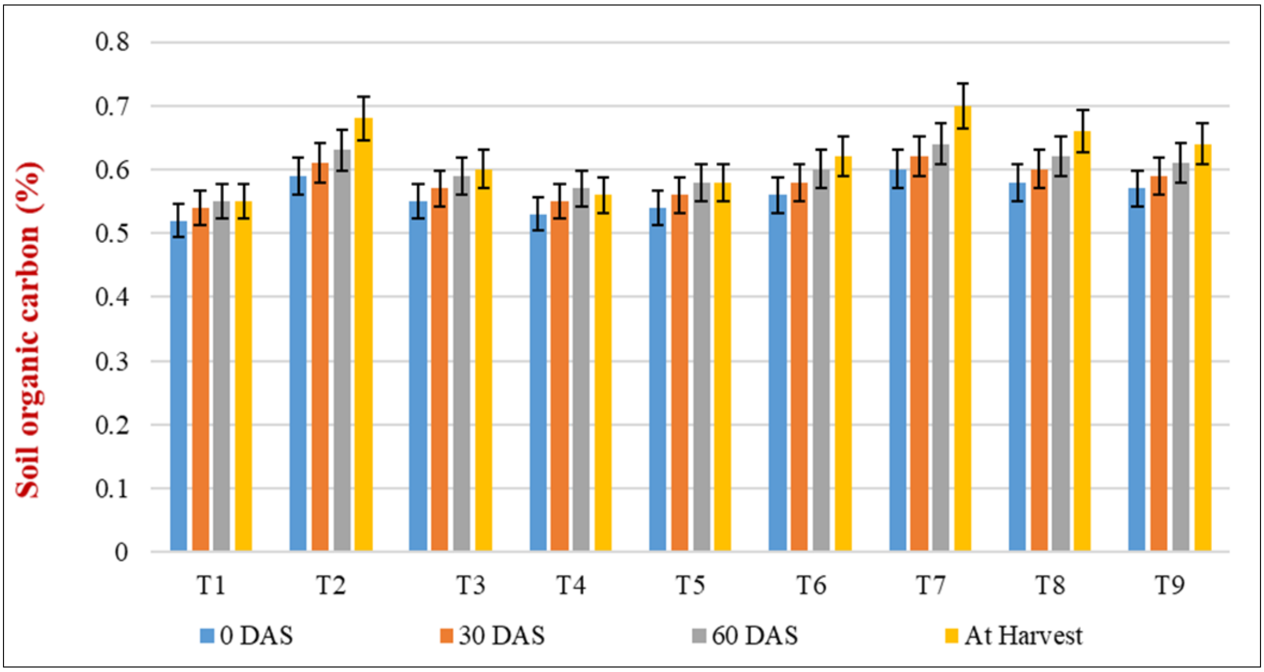

Fig 1: Soil organic carbon (%) of wheat as influenced by different natural, organic farming and integrated crop management practices at various time interval.

Chemical analysis

Available Nitrogen (kg ha^{-1})

The data pertaining to soil available nitrogen (kg/ha) in wheat and mustard cropping system quantified at initial and at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section and are presented in Table 3.

The findings revealed that different treatments imposed on wheat and mustard crop significantly affect the available nitrogen at harvest stage of 2021 and initial and harvest stage of 2021-2022 of experimentation. In the year 2020, the initial available nitrogen content in soil did not differ among the treatments, as this is the year of initiation of experiments. In 2021, which is the second year of experimentation significant differences were observed among treatments. In 2nd year 2021, of crop the initial highest soil available nitrogen (kg/ha) was observed in integrated crop management system using organic pest control (155.90 kg/ha), followed by integrated crop management system using inorganic pest control (155.40 kg/ha). Lowest was found under control treatment (133.38 kg/ha).

At harvest highest soil available nitrogen (kg/ha) was observed in integrated crop management using organic pest control (157.74 kg/ha). The treatment integrated crop management using inorganic pest control (157.26 kg/ha) was second in order. Lowest was found under control treatment (138.98 kg/ha) which was found at par with most of the treatments except integrated crop management system using inorganic pest control, organic farming system and natural farming practices. The available nitrogen quantified in integrated crop management system using organic pest control found significantly superior over integrated crop management system using inorganic pest control without intercropping. Maximum accumulation of available nitrogen 3.13 kg/ha was found in integrated crop management system using organic pest control, where 2.71 kg/ha was more nitrogen accumulated in case of integrated crop management system using inorganic pest control. The enhancement of soil available nitrogen (N) value under the integrated crop management system might be due release of different effect of the experiment. This might be due to fast mineralization of organic pool of nitrogen through higher microbial activity in these treatments with application of organic and inorganic sources. The organic inputs are important source of plant nutrient, especially N, and the supply of N from applied manures makes an important contribution to the nitrogen demand of growing crops (Abbasi *et al.*, 2007) [1]. Similarly, Tiwari *et al.* (2002) [38] reported the higher available N in treatments receiving organic inputs.

T_1: Control, T_2: Complete Natural Farming package (NF), T_3: NF- (Without Beejamrit+Ghanjeevamrit+jeevamrit), T_4: NF-Without crop residue mulching, T_5: NF-Without intercropping, T_6: NF-(Without whapasa), T_7: AI-NPOF package (organic farming practices), T_8: Integrated Crop Management (Organic pest control), T_9: Integrated Crop Management (Inorganic pest control).

Table 3: Available N in soil at initial and harvest of wheat (*Rabi Sea*son) as influenced by different natural farming, organic and integrated crop management practices at various time interval

	Available N (kg ha^{-1}) (initial)			Available N (kg ha^{-1}) (harvest)			Increase/Decrease
	2020	2021	Mean	2021	2022	Mean	Nitrogen
T_1	147.33	133.38	140.35	138.90	139.06	138.98	+ 1.37
T_2	157.35	142.40	149.87	146.27	148.46	147.36	+ 2.51
T_3	154.87	135.92	145.39	144.20	142.49	143.34	+ 2.05
T_4	149.47	133.52	141.49	138.70	141.30	140.10	+ 1.39
T_5	151.92	134.88	143.40	141.54	141.89	141.71	+ 1.69
T_6	155.60	136.65	146.12	145.77	143.32	144.54	+ 1.58
T_7	157.18	151.23	154.20	156.74	157.00	156.87	+ 2.67
T_8	165.85	155.90	160.87	154.30	161.19	157.74	+ 3.13
T_9	164.35	155.40	159.97	154.30	160.22	157.26	+ 2.71
S.E.M±	4.61	4.21	4.48	4.34	4.39	4.37	
CD (P=0.05)	NS	12.63	13.23	13.02	13.19	13.10	

Available Phosphorus (kg ha^{-1})

The data pertaining to soil available phosphorus (kg/ha) in wheat and mustard cropping system quantified at initial and at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section and are presented in Table 4.

The findings revealed that different treatments imposed on wheat and mustard crop did not affect the available phosphorus at harvest stage of 2021 and initial and harvest stage of 2021-2022 of experimentation. In the year 2020, the initial available phosphorus content in soil did not differ among the treatments, as this is the year of initiation of experiments. In 2nd year 2021, the initial highest soil available phosphorus was observed under integrated crop management system using organic pest control (18.70 kg/ha), followed by integrated crop management system using inorganic pest control (18.60 kg/ha). Lowest was found under control treatment (16.30 kg/ha). However all the treatments were found at par among each other.

At harvest highest soil available phosphorus (19.20 kg/ha) was observed in integrated crop management system using organic pest control followed by integrated crop management system using inorganic pest control (19.08 kg/ha). Lowest was found under control treatment (17.55 kg/ha). The treatments were found at par to each other. Maximum available phosphorus (kg/ha) accumulation was found in integrated crop management system using organic pest control where an accumulation of 0.78 kg/ha available phosphorus was observed, followed by integrated crop management system using inorganic pest control where 0.71 kg/ha available phosphorus increased in soil. In this study we found non-significant increase in available phosphorus (kg/ha) from initial to harvest due to adoption of different treatments. Sudhanshu *et al.* (2015) [36] also found higher availability of soil phosphorus when integrated with organic sources applied in wheat crop. Addition of organic manures influences P enrichment in soil (Johnston and Poulton, 1997) [15]. The increase in available phosphorus might be due to the organic acids, which were released during microbial decomposition of organic matter, which helped in the solubility of native phosphate (Bhardwaj and Omanwar, 1994) [6].

Table 4: Available P in soil at initial and harvest of wheat (*Rabi Sea*son) as influenced by different natural farming, organic and integrated crop management practices at various time intervals.

	Available P (kg ha^{-1}), (initial)			Available P (kg ha^{-1}), (harvest)			Increase/Decrease
	2020	2021	Mean	2021	2022	Mean	Phosphorus
T_1	19.74	16.30	18.02	17.72	17.36	17.55	+ 0.47
T_2	20.95	16.30	18.62	18.31	17.59	17.97	+ 0.65
T_3	20.50	16.40	18.45	18.29	17.52	17.92	+ 0.53
T_4	20.25	16.40	18.32	18.02	17.46	17.75	+ 0.57
T_5	20.40	16.30	18.35	18.21	17.37	17.80	+ 0.55
T_6	20.53	16.58	18.55	18.36	17.52	17.95	+ 0.60
T_7	20.40	17.40	18.90	18.86	18.92	18.22	+ 0.68
T_8	21.37	18.70	19.98	19.29	19.09	19.20	+ 0.78
T_9	20.89	18.60	19.79	19.12	19.02	19.08	+ 0.71
S.E.M±	0.60	0.50	0.55	0.54	0.53	0.53	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	

T_1: Control, T_2: Complete Natural Farming package (NF), T_3: NF- (Without Beejamrit+Ghanjeevamrit+jeevamrit), T_4: NF-Without crop residue mulching, T_5: NF-(Without intercropping), T_6: NF-(Without whapasa), T_7: AI-NPOF package (organic farming practices), T_8: Integrated Crop Management (Organic pest control), T_9: Integrated Crop Management (Inorganic pest control).

Available Potassium (kg ha^{-1})

The data pertaining to soil available potash (kg/ha) in wheat and mustard cropping system quantified at initial and at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section and are presented in Table 5. The findings revealed that different treatments imposed on wheat and mustard crop did not affect the available potash at harvest stage of 2021 and initial and harvest stage of 2021-2022 of experimentation. In the year 2020, the initial available potassium content in soil did not differ among the treatments, as this is the year of initiation of experiments. In 2nd year 2021, the initial highest soil available potash (379.19 kg/ha) was observed in integrated crop management system using organic pest control, followed by integrated crop management using inorganic pest control (376.32 kg/ha). Lowest was found under control treatments (363.31 kg/ha).

However all the treatments were found at par among each other. At harvest highest soil available potassium (386.05 kg/ha) was observed in integrated crop management system using organic pest control followed by integrated crop management system using inorganic pest control (384.85 kg/ha). Lowest was found organic farming practice (375.37 kg/ha). The treatments were found at par to each other. Maximum available potash (kg/ha) accumulation was found in integrated crop management system using organic pest control where 1.91 kg/ha increase in available potash (kg/ha) was observed followed by integrated crop management system using inorganic pest control where 1.44 kg/ha available potash (kg/ha) increased in soil. In this study we found non-significant increase in available potash (kg/ha) from initial to harvest due to adoption of different treatments. These results are agreement with Amit *et al.* (2009) [3] the beneficial effect of K the build-up of soil available potassium due to FYM application might be due to addition of potassium solubilizing action of certain organic acids produced during FYM decomposition and its greater capacity to hold potassium in the available form it also release organic collides with grater cation exchange sites that attract K from the non-exchangeable pool and applied K, which ultimately favour the available K (Majumdar *et al.*, 2005) [20]. Higher available potassium with application of FYM and vermi compost applied might be due to solubilizing action of certain organic acids produced during FYM decomposition and its greater capacity to hold potassium in the available form. Similar findings were also reported by Chaudhary (2021) [9] in wheat crop.

Table 5: Available K in soil at initial and harvest of wheat (*Rabi Sea*son) as influenced by different natural farming, organic and integrated crop management practices at various time interval.

	Available K (kg ha^{-1}), (initial)			Available K (kg ha^{-1}), (harvest)			Increase/Decrease
	2020	2021	Mean	2021	2022	Mean	Potassium
T_1	388.26	363.31	375.78	381.52	369.20	375.37	+ 0.41
T_2	389.65	373.70	381.67	383.76	376.99	380.38	+ 1.29
T_3	392.54	369.59	381.10	385.00	374.97	379.97	+ 1.13
T_4	390.17	368.22	379.19	382.60	373.91	378.30	+ 0.89
T_5	395.12	366.04	380.58	387.00	372.26	379.63	+ 0.92
T_6	391.14	371.19	381.16	381.62	378.32	379.98	+ 1.18
T_7	393.24	374.29	383.76	385.40	379.38	382.40	+ 1.34
T_8	398.14	379.19	388.66	389.09	383.00	386.05	+ 1.91
T_9	396.27	376.32	386.29	388.02	381.66	384.85	+ 1.44
S.E.M±	11.61	10.96	11.27	11.35	11.11	11.23	
CD (P=0.05)	NS	NS	NS	NS	NS	NS	

T_1: Control, T_2: Complete Natural Farming package (NF), T_3: NF-(Without Beejamrit+Ghanjeevamrit+jeevamrit), T_4: NF-Without crop residue mulching, T_5: NF-(Without intercropping), T_6: NF-(Without whapasa), T_7: AI-NPOF package (organic farming practices), T_8: Integrated Crop Management (Organic pest control), T_9: Integrated Crop Management (Inorganic pest control).

Yield analysis

Wheat equivalent yield (kg ha^{-1})

The data pertaining to seed yield (kg ha^{-1}) of wheat crop at harvest as influenced by different natural, organic farming and integrated crop management practices are interpreted in this section and are presented in Table 6.

The finding revealed that different treatments which were imposed on wheat crop significantly affected the seed yield at harvest of the crop due to adoption of three different types of nutrient practices during the crop cultivation in both the years on mean basis. At harvest highest seed yield (kg ha^{-1}) was observed in organic farming package (3492.21 kg ha^{-1}), followed by integrated crop management using organic pest control (3438.71 kg ha^{-1}). Lowest was found under control treatment (1398.50 kg ha^{-1}). The seed yield in treatment organic farming package was found at par with integrated crop management system using organic pest control and integrated crop management system using inorganic pest control and rest of the treatments found significantly inferior than organic farming practices. The yield of wheat crop depends on vegetative and reproductive growth of the plant which affected positively by application of organic manures i.e. FYM and vermi compost and supply of photosynthates for the formation of wheat grains. These results are in agreement with those reported by Yadav *et al.* (2009) [40] and Verma *et al.* (2015) [39]. Behera *et al.* (2009) [5] who reported that the application of organic manures, particularly FYM and vermi compost along with the *ghanjeevamrit* + *jeevamrit* to wheat crop was essential for improving productivity of wheat-mustard system. Applying higher quantities of organic nutrient at basal dose accumulate more dry matter and increase the vegetative growth compared to other splits. The similar result was reported by Singh and Singh (2005) [35].

Table 6: Crop equivalent yield of as influenced by different natural farming, organic and integrated crop management practices at various time interval

Treatment	Wheat equivalent yield (kgha^{-1})		
	2020	2021	Mean
T_1	1718.40	1078.51	1398.50
T_2	2334.83	2218.75	2276.79
T_3	1741.63	1498.84	1620.23
T_4	1976.37	1658.33	1817.35
T_5	2048.94	1734.45	1891.69
T_6	2143.22	1883.13	2013.75
T_7	3561.50	3422.92	3492.21
T_8	3495.73	3381.69	3438.71
T_9	3158.33	2932.17	3045.25
SEm±	76.87	70.71	73.75
CD (P=0.05)	230.48	212.00	221.11

The application of organic manures improved the yield compared to no organic manure. Higher biological yield was mainly due to combined effect of grains and straw. Similar results were also reported by Kumar *et al*. (2015) [19].

T_1: Control, T_2: Complete Natural Farming package (NF), T_3: NF- (Without Beejamrit+Ghanjeevamrit+jeevamrit), T4: NF-(Without crop residue mulching), T_5: NF-(Without intercropping), T_6: NF-(Without whapasa), T_7: AI-NPOF package (organic farming practices), T_8: Integrated Crop Management (Organic pest control), T_9: Integrated Crop Management (Inorganic pest control).

Mustard seed yield (kg ha^{-1})

The mustard crop was grown on different natural farming practices. The data pertaining to seed yield (kg ha^{-1}) at harvest was affected by different natural farming practices which are interpreted in this section and are presented in Table 7.

The finding revealed that different treatments which were imposed on mustard seed yield significantly affected the seed yield at harvest of the crop due to adoption of three different types of nutrient practices during the crop cultivation in both the years on mean basis. At harvest highest mustard seed yield (kg ha^{-1}) was observed in complete natural farming package (NF), (377.87 kg ha^{-1}), followed by NF-(without whapasa) (348.47 kg ha^{-1}). Lowest was found under NF- (without Beejamrit+ Ghanjeevamrit+jeevamrit) (249.78 kg ha^{-1}). The seed yield in treatment complete natural farming package (NF), was found significantly superior over NF-(without whapasa). These results are in conformity with those of Joshi *et al*., (2021) [16], who stated that, application of *beejamrit*, *ghanjeevamrit and jeevamrit* along with crop residue significantly increased the grain yield of mustard over control treatment during two years of experiment. Sushila and Giri (2000) [37] reported that natural farming practice involves to improved the production of crop and significantly increased the yield of mustard.

Table 7: Yield of maize as influenced by different natural farming management practices

Treatment	Maize green cob yield (kg ha^{-1})		
	2020	**2021**	**Mean**
T_2	1388.60	4425.27	2906.9
T_3	1002.50	3716.37	2359.4
T_4	1171.80	3629.53	2400.7
T_6	1373.67	4370.60	2872.1
S.E.M±	48.46	130.95	72.64
CD (P=0.05)	167.71	453.15	251.38

T_2: Complete Natural Farming package (NF), T_3: NF- (Without Beejamrit+Ghanjeevamrit+jeevamrit), T_4: NF-(Without crop residue mulching), T_6: NF-(Without whapasa).

Conclusion

The study highlights the critical need for sustainable agricultural practices in the face of increasing food demand and environmental challenges. The comparison of various nutrient management systems, including Complete Natural Farming, Organic Farming, and Integrated Crop Management, demonstrates that these approaches can significantly enhance soil health and crop productivity. Notably, the Complete Natural Farming package yielded the highest results for both wheat and mustard crops, indicating its potential as a viable alternative to conventional methods. As India approaches a population of 1.51 billion by 2030, adopting eco-friendly farming techniques will be essential for ensuring food security while preserving soil health and biodiversity. Future research should focus on optimizing these practices across diverse agro-climatic conditions to maximize their benefits.

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