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Impact of different management practices on the Physicochemical and chemical properties of soil in heat+mustard intercropping systems

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Abstract
A field experiment was conducted during the *rabi* seasons of 2022-23 and 2023-24 under the All India Network Programme on Organic Farming (AI-NPOF) at the Instructional Research Farm, Krishi Nagar, JNKVV, Jabalpur, Madhya Pradesh. The study evaluated six crop management practices in a randomized block design with four replications using wheat (JW-3382) as the base crop and mustard (Pusa Agrani) as the intercrop in an 8:2 row arrangement. Treatments included, T_1: Control (Excluding all inputs except labour for weeding), T_2: Complete Natural Farming Practices, T_3: Organic Management Practices, T_4: ICM (50% nutrient through organic and 50% nutrient through inorganic sources + natural pesticides), T_5: ICM (50% nutrient through organic and 50% nutrient through inorganic sources + need based pesticides) and T_6: Conventional Management Practices. The results indicated that soil organic carbon, pH, and electrical conductivity (EC) were not significantly influenced across treatments, though a general trend of decreased organic carbon, increased pH, and decreased EC was observed compared to initial values. The highest organic carbon (0.616%) and pH (6.818) were recorded under Organic Management Practices, while the highest EC (0.217 dS m^{-1}) was observed under Organic Management Practices and ICM in pooled analysis. Soil nutrient availability (N, P, K) was significantly influenced by the treatments. Organic Management Practices showed the highest available N (300.25 kg ha^{-1}), P (21.17 kg ha^{-1}), and K (318.61 kg ha^{-1}) in pooled analysis, outperforming all other treatments except control.

Keywords: Electrical conductivity, integrated crop management (ICM), natural farming practices, nutrient and organic farming

Introduction
By 2050 (FAO), the Food and Agriculture Organization (FAO) estimates that global food production must increase by 70% to meet the demands of a growing population and evolving consumption patterns driven by an expanding middle class. India, projected to become the most populous country by 2030 with 1.51 billion people (FAO, 2017), faces the critical challenge of ensuring food security for its population. The adoption of large-scale agricultural practices or production technologies lacking scientific validation poses risks to crop productivity and raises concerns about achieving food and nutrition security. India's agricultural sector has undergone significant technological transformations, notably through the Green Revolution (GR), which introduced technology-driven agricultural intensification. While this shift enabled the transition from food deficit to surplus, it also brought adverse consequences, including soil degradation, biodiversity loss, rising input costs, and increased reliance on chemical fertilizers and pesticides. Despite intensive inputs, crop productivity has stagnated or declined, exacerbated by market volatility and climate change. These challenges have rendered agriculture less profitable, pushing many farmers into debt and contributing to widespread distress. In response, alternative approaches such as Organic Farming and Natural Farming (NF), including Zero Budget Natural Farming (ZBNF), have gained attention. Wheat (*Triticum aestivum* L.), a staple cereal crop globally, plays a vital role in nutritional security and economic well-being. Its nutritional composition includes 8.0-15.0% protein, 60-68% starch, 1.5-2.0% fat, 2.0-2.5% cellulose, and 1.5-2.0% minerals and vitamins (Sharma, 2000; Rueda-Ayala *et al.*, 2011) [18].

Globally, wheat is cultivated on 223.4 million hectares, producing 778.6 million tons with an average yield of 3,546 kg ha-1 (USDA, 2021), making it the second most extensively grown cereal after maize. It accounts for nearly half of the caloric intake for the global population (Ramdas *et al.*, 2019) [23]. In India, wheat is grown on 31.62 million hectares, yielding 109.2 million tons with an average productivity of 3,420 kg ha-1 (USDA, 2021). It contributes approximately 35% of the nation's grain supply. In Madhya Pradesh, wheat cultivation spans 10.2 million hectares, with a production of 16.52 million tons and an average productivity of 3,298 kg ha-1 (Department of Agriculture, M.P., 2021).

Mustard (Brassica juncea L.), the second most cultivated oilseed crop in India after groundnut, is grown primarily for its edible oil. India ranks as the third-largest producer globally, with a cultivation area of 8.06 million hectares, yielding 11.75 million tons, and an average productivity of 1,458 kg ha-1 (Agricultural Statistics at a Glance, 2022). In Madhya Pradesh, mustard is grown on 1.23 million hectares, producing 1.69 million tons at a productivity of 1,376 kg ha-1 (Agricultural Statistics at a Glance, 2022). The Subhas Palekar Natural Farming (SPNF) system, designed for small and marginal farmers, utilizes locally available inputs such as desi cow (Bos indicus) urine, dung, lime, gram flour, and soil for fermentation, which is later applied as foliar spray or fertigation. According to Palekar, these inputs enhance soil microbial activity, thereby mineralizing macro- and micronutrients and making them accessible to crops. Combining cereal-legume intercropping with natural farming practices can reduce greenhouse gas emissions, enhance yield stability, and maintain soil fertility. Natural farming minimizes the need for purchased fertilizers and pesticides (Bishnoi *et al.*, 2017) [3]. Its core components include Beejamrit, Jeevamrit, mulching (Acchadana), and moisture (Whaapasa), all of which promote resource efficiency and soil and water conservation. Similarly, organic farming offers several benefits over conventional practices. Organic manures supply essential plant nutrients, improve physiological functions, and enhance soil physical properties such as aeration, water retention, and tilth. They also improve chemical properties by supplying and retaining nutrients while reducing the need for synthetic inputs. This approach supports sustainability by providing pollution-free food, reducing soil degradation, and promoting microbial activity. Over-reliance on chemical-based farming has led to declining soil health, necessitating eco-friendly alternatives. Organic farming, which avoids chemical fertilizers, pesticides, and synthetic inputs, relies on crop residues, animal manures, legumes, and biological pest control to maintain soil health and nutrient availability (Smith *et al.*, 2020) [19]. Integrated Crop Management (ICM) represents another holistic approach, combining traditional knowledge with modern technologies. ICM incorporates practices such as crop rotation, intercropping, organic amendments, minimal tillage, efficient irrigation, and biodiversity enhancement to optimize resource use and improve productivity. By integrating diverse strategies, ICM reduces environmental impacts, lowers input costs, and supports smallholder farmers. Considering these aspects, this study investigates the productivity of wheat and mustard intercropping systems during the Rabi season under natural farming, organic farming, ICM, and conventional farming practices.

Material and Methods

The field experiment was conducted under All India Network Programme on Organic Farming (AI-NPOF) during Rabi seasons of 2022-23 and 2023-24 at Instructional Research farm, Krishi Nagar Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur (M. P.). The experiment was laid out in a Randomized block design with four replications. The treatment comprises of six crop management practices during the Rabi season of 2022-23 and 2023-24. Wheat was taken as base crop and mustard was taken as an intercrop in all the treatment with 8:2 row arrangement. Wheat variety JW-3382 and mustard variety Pusa Agrani were taken in the experiment. The spacing used for wheat and mustard was 22.5 cm row to row. The sowing date of wheat and mustard was 18th November and 10th November and harvesting date 22nd March and 13th March during Rabi 2022 and 2023, respectively. Prior to sowing, seeds were treated with Beejamrit @ 2.5 litres for 10 kg seed in treatment 2 and with Trichoderma and Pseudomonas @ 5 g per kg seed in treatment 3, 4 and 5. The treatment details are presented in Table 1.

Nutrient Management was done as per the treatment. In case of AI-NPOF treatment 75% of recommended dose of nutrient was applied through organic sources i.e., 1/3rd FYM + 1/3rd Vermicompost + 1/3rd Non-Edible oil cake and two foliar spray of cow urine and Vermiwash @ 10% at 30 and 50 DAS while in the treatment integrated crop management 50% nutrient through organic and 50% nutrient applied through inorganic sources and in Conventional management Practices 100% nutrient applied through chemical fertilizers through urea, single super phosphate (SSP) and muriate of potash (MOP) at the rate of 120:60:40 kg NPK ha-1 in both the years. Full quantity of P2O5 and K2O were given as basal dose at the time of sowing nitrogen was applied in three split doses.

Table 1: Treatment detail

T_1	**Control: (No addition of any input except labour for operations including weeding)**
T_2	Complete Natural Farming Practices: (1. Beejamrit + Ghanjeevamrit + Jeevamrit, 2. Crop residue mulching, 3. Intercropping, 4. Whapasa) [Pre- monsoon dry sowing (PDMS) / Multi- variate cropping (MVC) with multiple crops during fallow + Prophylactic/preventive method of application of Neemaster, Dashparni ark, Brahmaster, Neem seed kernel extract, border crop, trap crop, seed treatment with *Trichoderma, pseudomonas* and Curative application of leaf extracts of Datura,vitex, Agniaster, sour butter milk, 2G/ 3G extract and use of biocontrol agents and mechanical traps).
T_3	Organic Management Practices: (AI-NPOF package): (75% RDN through organic sources + two foliar spray of 10% cow urine and vermiwash at 30 and 50 DAS)
T_4	ICM (50% nutrient through organic and 50% nutrient through inorganic sources + natural/organic pesticides for pest management)
T_5	ICM (50% nutrient through organic and 50% nutrient through inorganic + need based pesticides)
T_6	Conventional management Practices: (RDN 120:60:40 Kg ha^{-1} N: P_2O_5: K_2O)

RDN for Wheat + Mustard- 120:60:40 Kg ha-1 N: P2O5: K2O, ICM - Integrated crop management

Table 2: Effect of different management practices on available Organic carbon, pH and Electric conductivity in soil under different treatment

Treatment		OC (%)			pH			EC (dS/m)		
		2022- 23	2023-24	Pooled	2022- 23	2023-24	Pooled	2022- 23	2023-24	Pooled
T_1	Control (Excluding all inputs except labour for weeding)	0.593	0.598	0.595	6.785	6.793	6.789	0.205	0.198	0.201
T_2	Complete Natural Farming Practices	0.613	0.611	0.611	6.813	6.81	6.811	0.215	0.21	0.213
T_3	Organic Management Practices	0.613	0.62	0.616	6.815	6.82	6.818	0.22	0.213	0.217
T_4	ICM (50% nutrient through organic and 50% nutrient through inorganic sources + natural pesticides)	0.606	0.605	0.603	6.808	6.803	6.805	0.215	0.211	0.213
T_5	ICM (50% nutrient through organic and 50% nutrient through inorganic sources + need based pesticides)	0.605	0.605	0.605	6.8	6.808	6.804	0.213	0.214	0.213
T_6	Conventional Management Practices	0.605	0.6	0.603	6.79	6.79	6.79	0.205	0.203	0.204
SEm +		0.005	0.008	0.005	0.011	0.012	0.008	0.005	0.005	0.004
CD (5%)		NS	NS	NS	NS	NS	NS	NS	NS	NS

Initial soil organic carbon = 0.610, soil pH = 6.7, EC = 0.20

Table 3: Effect of different management practices on available N (kg/ha), available P (kg/ha) and available K (kg/ha) in soil under different treatment

Treatment		Available N (kg/ha)			Available P (kg/ha)			Available K (kg/ha)		
		2022- 23	2023-24	Pooled	2022- 23	2023-24	Pooled	2022- 23	2023-24	Pooled
T_1	Control (Excluding all inputs except labour for weeding)	269.95	267.13	268.54	16.05	16.25	16.15	287.5	286.6	287.05
T_2	Complete Natural Farming Practices	297.75	296.23	296.99	19.33	19.63	19.48	305.4	303.83	304.61
T_3	Organic Management Practices	300.65	299.85	300.25	21.15	21.19	21.17	319.15	318.08	318.61
T_4	ICM (50% nutrient through organic and 50% nutrient through inorganic sources + natural pesticides)	296.98	296.48	296.73	20.08	20.83	20.45	313.88	310.68	312.28
T_5	ICM (50% nutrient through organic and 50% nutrient through inorganic sources + need based pesticides)	296.85	296.53	296.69	19.9	20.05	19.98	314.43	313.43	313.93
T_6	Conventional Management Practices	294.75	293.6	294.18	19.45	19.65	19.55	312.5	310.63	311.56
SEm +		0.54	1.05	0.59	0.24	0.41	0.24	0.55	1.25	0.68
CD (5%)		1.64	3.15	1.7	0.73	1.24	0.69	1.66	3.76	1.97

Initial soil N, P and K 281.43, 20.35 and 272.12 (kg ha^{-1})

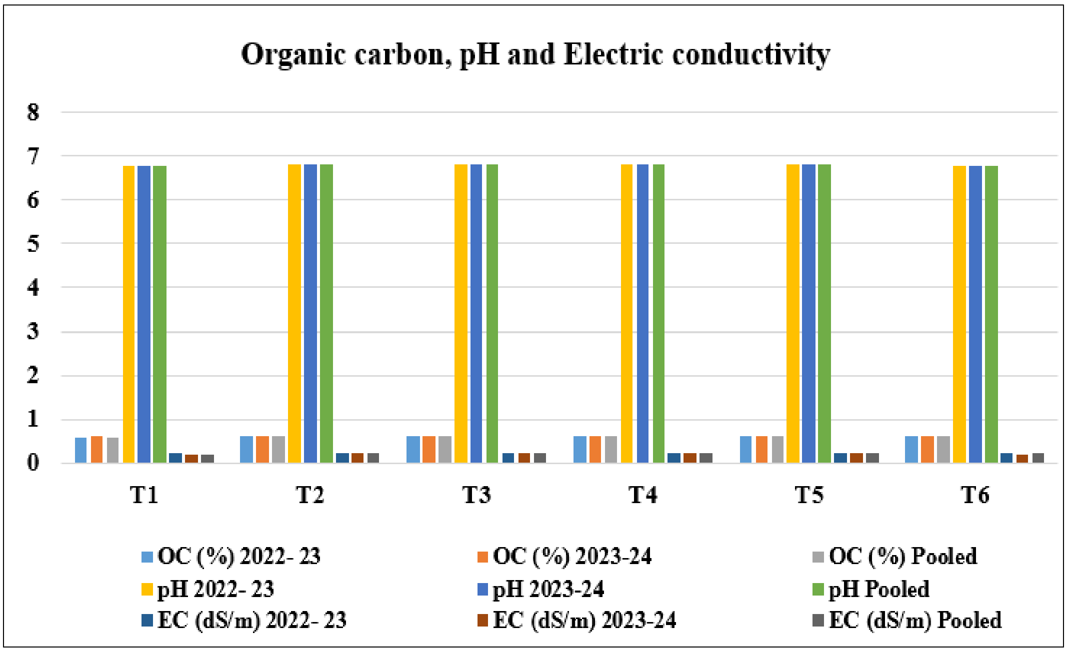

Fig 1: Effect of different management practices on available Organic carbon, pH and Electric conductivity in soil under different treatment

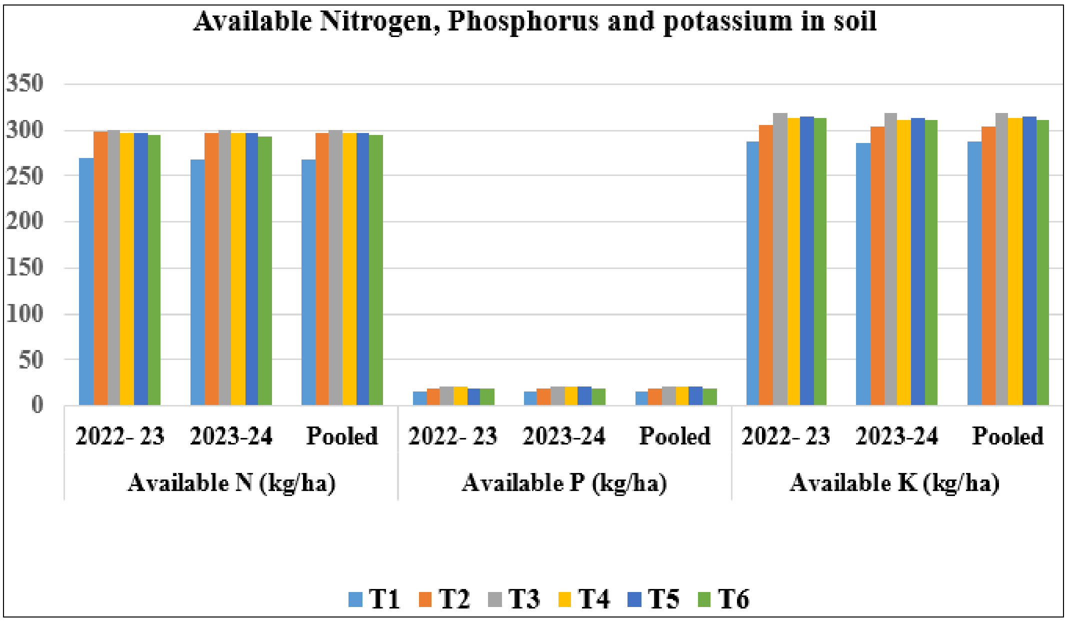

Fig 2: Effect of different management practices on available Nitrogen, Phosphorus and potassium in soil under different treatment

Result and Discussion

Organic carbon (%), soil pH and EC (dS m-1)

The data pertaining to changes in physico-chemical properties of soil at harvest of wheat + mustard intercropping system (Rabi season) under various treatments are presented in Table 6.1. It is apparent from the result that different treatment showed no-significant impact in organic carbon, soil pH and EC of the soil during Rabi season 2022-23, 2023-24 and pooled basis. However, there was decrease in soil organic carbon except Organic Management Practices and Complete Natural Farming Practices, increase in soil pH and decrease in EC as compared to initial values in all the treatments. Among the treatments the highest organic carbon (0.613, 0.620 and 0.616%), soil pH (6.815, 6.820, 6.818) was recorded under Organic Management Practices during both the years and pooled basis. The increase in pH values across the treatments was consistent. This enhancement in soil pH could be attributed to the release of various salts that function as buffering agents, helping to move the pH towards neutrality. Similar results for pH have also been reported Pathak *et al.* (2007) [15] and Sharma *et al.* (2007) [18]. However highest EC (0.220, 0.214 and 0.217 dS m-1) was observed under Organic Management Practices during first year and pooled basis and ICM (50% nutrient through organic and 50% nutrient through inorganic sources + need based pesticides) during the second year of experiment. On the other hand, the lowest values recorded under control treatment. The increase in EC observed under organic farming practices could be attributed to the application of organic inputs such as FYM and vermicompost, which likely elevated the soil's salt concentration compared to the control treatment. Higher EC levels in treatments involving organic manures and nutrient management may result from the release of various salts. These findings align closely with those of Gore and Sreenivasa (2011) [7] and Shaikh and Gachande (2016) [17]], who reported that EC values were not significantly affected by the use of organic manures and nutrient management, whether applied individually or in combination at varying nutrient levels. Organic nutrients (manures and root biomass) have the largest effect in soil organic carbon (Khaleel *et al.*, 1981; Badanur *et al.*, 1990) [10, 2]. Tiwari *et al.* (2002) [21] and Kaur *et al.* (2005) [9] 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) [13]; Ramesh *et al.* (2009) [16] and Panwar *et al.* (2010) [14] reported higher soil organic carbon in the treatments receiving organic nutrients over a long term period. Chang *et al.* (2014) [4] 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.* (2013) [12] also reported a significant increase in soil organic carbon in wheat cropping system due to addition of FYM and crop residues.

Available N, P and K in soil (kg ha-1)

Data related to availability of N, P and K in soil after harvest of wheat + mustard intercropping system (Rabi season) are presented in Table 6.2. The availability of N, P and K in soil was significantly influenced by the various treatments during both the years and on pooled analysis basis. Organic Management Practices showed the highest value of available N (300.65, 299.85 and 300.25 kg ha-1), available P (21.15, 21.19 and 21.17 kg ha-1) and available K (319.15, 318.08 and 318.61 kg ha-1) during both the years and on pooled basis, respectively which was comparable with rest of the treatments except 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) [21] reported the higher available N in treatments receiving organic inputs. Sudhanshu *et al.* (2015) [20] 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) [8]. The enhanced capacity to retain potassium in its available form, along with the release of organic colloids containing numerous cation exchange sites, facilitates the attraction of potassium from both the non-exchangeable pool and applied sources, ultimately increasing available potassium (Majumdar *et al.*, 2005) [11]. The higher availability of potassium with the application of FYM and vermicompost may be attributed to the solubilizing effect of organic acids generated during FYM decomposition and its ability to retain potassium in a readily accessible form. Similar observations were reported by Chaudhary (2021) in wheat crops.

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