International Journal of Plant & Soil Science

Volume 37, Issue 1, Page 550-563, 2025; Article no.IJPSS.130687
ISSN: 2320-7035

Effect of Different Management Practices on Yield Attributes and Productivity of Wheat + Mustard Intercropping System

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

Article Information

DOI: https://doi.org/10.9734/ijpss/2025/v37i15295

Open Peer Review History:
This journal follows the Advanced Open Peer Review policy. Identity of the Reviewers, Editor(s) and additional Reviewers, peer review comments, different versions of the manuscript, comments of the editors, etc are available here: https://pr.sdiarticle5.com/review-history/130687

Original Research Article

Received: 29/11/2024
Accepted: 31/01/2025
Published: 04/02/2025

ABSTRACT

The present investigation entitled "Effect of natural farming, organic farming, integrated crop management and conventional management practices on yield attributes and productivity of Wheat + Mustard intercropping system" was conducted under All India Network Programme on Organic Farming (AI-NPOF) during *rabi* season of 2022-23 and 2023-24 at Instructional Research farm, Krishi Nagar Jawaharlal Nehru Krishi Vishwavidyalaya, Jabalpur (M.P). The soil of experiment was

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Cite as: *Kumbhare, Rahul, P.K. Mishra, R. P. Sahu, Vikas Gupta, Raghav Patel, and Kirti Singh. 2025. "Effect of Different Management Practices on Yield Attributes and Productivity of Wheat + Mustard Intercropping System". International Journal of Plant & Soil Science 37 (1):550-63. https://doi.org/10.9734/ijpss/2025/v37i15295.*

sandy clay loam, neutral in reaction (pH 6.7), low in organic carbon (0.62 %), medium in available nitrogen (281.43 kg ha^{-1}), medium in available phosphorus (20.35 kg ha^{-1}) and high in available potassium (272.12 kg ha^{-1}). The experiment was carried out in a Randomized block design with six treatments and four replications. The treatment comprises of T1- Control (No addition of any input except labour for operations including weeding), T2- Complete Natural Farming Practices (1. Beejamrit + Ghanjeevamrit + Jeevamrit 2. Crop residue mulching 3. Intercropping 4. Whapasa), T3- 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), T4-ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural/organic pesticides for pest management), T5-ICM (50 % nutrient through organic and 50 % nutrient through inorganic + need based pesticides) and T6-Conventional Management Practices (RDN 120:60:40 Kg ha^{-1} N: P_2O_5: K_2O ha^{-1}). The result of the experiment revealed that conventional management practices i.e. RDN @120:60:40 Kg ha-1 of N: P2O5: K2O proved to be best for wheat + mustard intercropping system in terms of yield attributes and yield and this was followed by integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources and pest management with need based pesticides. Higher wheat equivalent yield was recorded under conventional management practices.

Keywords: Complete natural farming; organic farming; integrated crop management; conventional management practices.

1. 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). 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.

India's agriculture sector has experienced numerous technological advancements over the years. The Green Revolution (GR), which introduced technology-driven agricultural intensification, transformed India from a food-deficit nation to one with a surplus. However, this shift also brought several negative consequences, including soil degradation, loss of biodiversity, increasing cultivation costs, and rising dependency on chemical fertilizers and pesticides. Despite these inputs, crop productivity began to stagnate or decline, exacerbated by volatile market conditions and the impacts of climate change. As a result, agriculture became less remunerative, pushing many farmers into debt and contributing to widespread distress in the farming sector. In response, practices such as Organic Farming and Natural Farming (NF), including Zero Budget Natural Farming (ZBNF), have gained prominence as potential alternatives.

Wheat (*Triticum aestivum* L.) is the most important cereal crop for the majority of the world's population. It renders a valuable contribution in the nutritional security and financial well –being of larger part of global population. It contains 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 (B complex and vitamin E) which is used as feed for both humans and animals (Sharma, 2000 and Rueda-Ayala et al., 2011). Globally the total area, production and productivity of wheat are 223.40 m ha, 778.6 mt and 3546 kg ha-1 respectively (USDA, 2021), positioning it as the second most extensively produced cereal crop, following maize. Globally, wheat is among the most significant staple food grains, fulfilling nearly half of the caloric requirements of the population (Ramdas et al., 2019). In India, the total area under wheat cultivation is 31.62 million hectares, with a production of 109.2 million tons and an average productivity of 3,420 kg per hectare (USDA, 2021). As one of India's principal cereal crops, wheat, a high-energy winter cereal, contributes approximately 35% to the nation's grain supply. In Madhya Pradesh, wheat is cultivated over an area of 10.2 million hectares, yielding 16.52 million tons with a productivity of 3,298 kg per hectare (Department of Agriculture, M.P., 2021).

Mustard (*Brassica juncea* L.) is the second most extensively cultivated oilseed crop in India, following groundnut. It is primarily grown for its edible oil, widely used for cooking and frying. India ranks as the third-largest mustard producer globally, with cultivation spanning 8.06 million hectares, yielding 11.75 million tonnes, and an average productivity of 1,458 kg per hectare (Agricultural Statistics at a Glance, 2022). Mustard is grown as a winter crop in the tropical and subtropical regions of India. Indian mustard, a prominent brassica species, is cultivated nationwide under diverse climatic and agro-ecological conditions. In Madhya Pradesh, mustard is grown on 1.23 million hectares, producing 1.69 million tonnes, with a productivity of 1,376 kg per hectare (Agricultural Statistics at a Glance, 2022).

A new farming system came into light courtesy of Subhas Palekar Natural Farming System (SPNF) that is tailored fit for small and marginal farmer and Indian farmers that uses local indigents for farming like desi cow (Bos indicus) urine, cow dung, lime, gram flour and handful of soil and after fermentation it is used for foliar spray or fertigation. According to Subhas Palekar, natural farming components have high microbial load which upon application increase the soil flora that mineralize the soil macro and micronutrients and make them available for plant use. Conjoint use of cereal-legume intercropping and natural farming systems can be ideal to reduce greenhouse gas emission and increase yield stability while maintaining soil fertility. Natural farming, as the name implies, pooleds that farmers do not need to purchase fertilizers and pesticides to ensure the growth of crops (Bishnoi et al., 2017). Natural Farming (NF) is a distinct chemicalfree 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) Four pillars or components of natural farming are Beejamrit, Jeevamrit, Acchadana (Mulching) and Whaapasa (Moisture).

Natural farming is a resource efficient farming system which minimizes the use of external resources and also restores the quality of soil and water resources. The importance of natural farming is to minimize the use of external inputs to the farmland and enrich soil through the propagation of soil microbes. It encourages the natural symbiosis of soil micro flora and crop plants. The natural inputs used in organic farming and natural farming are easily available, releases nutrients slowly, supplies macro and micro nutrients and provides favorable soil environment for microbial population and soil enzymes.

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 reactions. They reduce the need for purchased inputs.

General acceptance of organic farming and natural farming is not only due to the greater demand for pollution-free food but also due to natural advantage in supporting sustainability in agriculture. Though conventional farming helps in getting substantial yields, indiscriminate use of inorganic fertilizers and continuous farming has resulted in various soil hazards ultimately leading to lower productivity. Additionally, over emphasis on conventional farming has resulted in deterioration of soil and plant health. Restoring soil health by reverting to non-chemical agriculture has assumed great importance to attain sustainability in production. In this search for eco-friendly alternate systems of farming, organic and natural farming are increasingly becoming popular among the farming community with limited use of cow dung and cow urine (Patil et al., 2022). Adopting integrated nutrient management practices (organic manures, liquid manures with fertilizers) and certified organic agriculture (organic manures and biofertilizers) can reduce reliance on chemical inputs as well as make agriculture environmentally and economically sound. Organic farming is a production system that largely excludes or avoids the use of chemical fertilizers, pesticides, growth regulators, preservatives, livestock feed additives and totally rely on crop residues, animal manures, legumes, green manures, off-farm wastes, mechanical cultivation, mineral nutrient bearing rocks and biological pest control to maintain soil health, supply plant nutrients and minimize insects, weeds and other pests. Organic farming systems rely on the management of soil organic matter to enhance the chemical, biological and physical properties of the soil. Soil fertility management in organic systems depends on biologically-derived nutrient instead of using readily soluble forms of nutrients; less available forms of nutrients such as those in bulky organic materials. This requires the release of nutrients to the plant via the activity of soil microbes and soil animals. Apart from organic farming, another farming system called natural farming also involves similar components, which mainly depend on the use of naturally available inputs (Smith et al., 2020). Integrated Crop Management (ICM) practices encompass a holistic approach to sustainable agriculture, combining traditional knowledge with modern technology to optimize resource use and improve crop yields. ICM involves a range of strategies such as crop rotation, intercropping, soil fertility management, and the use of judicious and inorganic inputs. It emphasizes the importance of maintaining soil health through organic amendments and minimal tillage, conserving water through efficient irrigation systems, and enhancing biodiversity to naturally control pests and diseases. By integrating these diverse practices, ICM aims to increase productivity, reduce environmental impact, and support smallholder farmers by lowering input costs and promoting long-term agricultural sustainability.

Keeping the aforementioned things in mind, in this study wheat-mustard crop will be grown in rabi season which normally grown as inter crops. The present study was carried out to compare the productivity of wheat and associated intercrops under natural farming, organic farming, integrated crop management and conventional management practices.

2. MATERIALS 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 18 th November and 10 th November and harvesting date 22 nd March and 13 th March during rabi 2022 and 2023, respectively. Prior to sowing, seeds were treated with Beejamrit @ 2.5 litres for 10kg 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.

2.1 ICM-Integrated Crop Management

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.e1/3rdFYM + 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.

RDN for Wheat + Mustard- 120:60:40 Kg ha^{-1} N: P2O5: K2O

Formula of Wheat equivalent yield (WEY)

$$\text{WEY} = \frac{Mustard\ \ yield \times Mustard\ price}{Wheat\ Price}$$

Table 1. Treatment detail

T1	Control (No addition of any input except labour for operations including weeding)
T2	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 wuth

	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)
T3	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)
T4	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural/organic pesticides for pest management)
T5	ICM (50 % nutrient through organic and 50 % nutrient through inorganic + need based pesticides)
T6	Conventional management Practices (RDN 120:60:40 Kg ha-1 N: P2O5: K2O)

3. RESULTS

3.1 Wheat

3.1.1 Effective tillers m^{-2}

Data pertaining to effective tillers m^{-2} revealed that natural farming, organic farming, integrated crop management and conventional farming practices significantly influenced the effective tillers m^{-2} (Table 2). Conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O proved to be the best and significantly enhanced the effective tillers m^{-2} (210.4, 211.8 and 211.1) which was at par with Integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources and use of need based pesticides for pest management during the first of the experiment. On the contrary minimum effective tillers m^{-2} was observed in control treatment (165.1, 167.7 and 166.4).

3.1.2 Earhead length (cm)

Earhead length (cm) was significantly influenced due to natural farming, organic farming, integrated crop management and conventional farming practices during both the years as well as on the pooled basis (Table 2). The maximum earhead length (7.97, 8.03 and 8.00 cm) during 2022-23, 2023-24 and pooled basis, respectively was observed from Conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O and which was at par with integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources (need based pesticides for pest management) during both the year and pooled basis and 50 % RDN through organic and 50 % RDN through inorganic sources (natural/organic pesticides for pest management) during the first year of experiment. However, the lowest effective length (5.85, 5.96 and 5.9 cm) was observed in control treatment.

3.1.3 Grains Earhead^{-1}

The data observed on grains earhead^{-1} are presented in Table 2. It was observed that different treatments significantly influenced grains earhead^{-1}. Significantly higher number of grain earhead-1 (28.58, 28.58 and 28.58) during 2022-23, 2023-24 and on pooled basis, respectively were obtained under conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O which was statistically at par with Integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources and use of need based pesticides for pest management during both the year and on pooled basis. On the contrary the lowest number of grains earhead^{-1} (15.55, 15.75 and 15.65) was recorded in control treatment during both the years and on pooled basis respectively.

3.1.4 Test weight (g)

Data on test weight (g) are presented in Table 2. Test weight was not significantly influenced due to natural farming, organic farming, integrated crop management and conventional farming practices during both the years and on pooled basis, respectively. Integrated crop management *i.e.* 50 % RDN through organic + 50 % RDN through inorganic sources (need based pesticides for pest management) recorded the highest test weight (41.42 and 41.17 g) during the first year and on the pooled basis, while, conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O recorded highest test weight (41.03 g) during second year of investigation. However, the lowest test weight (38.65, 39.24 and 38.95 g) was observed in control treatment. However all the treatments were found at par with each other.

3.1.5 Grain yield (kg ha^{-1})

Data related to grain yield of wheat are presented in Table 3. Grain yield significantly varied due to natural farming, organic farming, integrated crop management and conventional farming practices. Among the different treatments, conventional management Practices i.e. RDN @120:60:40 Kg ha-1 of N: P2O5: K2O, produced significantly higher grain yield (3095, 3143 and 3119 kg ha^{-1}) and was statistically at par with 50 % RDN through organic + 50 % RDN through inorganic sources (need based pesticides for pest management) which produced grain yield (3016, 3083 and 3050 kg ha^{-1}) during both the years and on pooled basis, respectively. However, the lowest grain yield (1112, 1246 and 1179 kg ha-1) was observed in control treatment followed by natural farming and organic farming practices.

3.1.6 Straw yield (kg ha^{-1})

The data on straw yield of wheat as influenced by natural farming, organic farming, integrated crop management and conventional farming practices are presented in Table 3. The finding revealed that different treatments had significant effect on straw yield of wheat. Significantly the highest straw yield (5413, 5069 and 5241kg ha-1) was noted under conventional management Practices i.e. RDN @120:60:40 Kg ha-1 of N: P2O5: K2O during both the years and on pooled basis, respectively which was at par to integrated crop management with 50 % RDN through organic + 50 % RDN through inorganic sources and pest management with need based pesticides. On the contrary, the lowest straw yield (1903, 2368 and 2135 kg ha^{-1}) was observed in control treatment followed by natural farming, AI-NPOF package (75 % RDN through organic sources + two foliar spray of 10 % cow urine and vermiwash at 30 and 50 DAS) and Integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources (natural/organic pesticides for pest management).

3.2 Mustard

3.2.1 Siliqua plant^{-1}

Data on siliqua plant^{-1} was observed at the time of harvesting and presented in Table 4. This parameter was significantly by natural farming, organic farming, integrated crop management and conventional farming practices.

The highest siliqua plant^{-1} (165.0,164.6 and 164.8) during 2022-23, 2023-24 and on pooled basis, respectively was observed with conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O which was at par with Integrated crop management along with need based pesticides application *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources during both the years and on pooled basis, respectively. On the contrary the lowest siliqua plant^{-1} was recorded in control treatment followed by complete natural farming, AI-NPOF package (75 % RDN through organic sources + two foliar spray of 10 % cow urine and vermiwash at 30 and 50 DAS) and Integrated crop management along with natural/organic pesticides application *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources

3.2.2 Length of siliqua (cm)

Length of siliqua was significantly influenced due to natural farming, organic farming, integrated crop management and conventional farming practices during both the year as well as pooled basis (Table 4).

Among the different treatments, the maximum length of siliqua (4.91, 5.10 and 5.00 cm) during 2022-23, 2023-24 and on pooled basis respectively was observed under conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O and was comparable with Integrated crop management *i.e.* 50 % RDN through organic + 50 % RDN through inorganic sources (need based pesticides for pest management). However, the lowest Length of siliqua (3.48, 3.55 and 3.52 cm) was observed in control treatment followed by complete natural farming, AI-NPOF package (75 % RDN through organic sources + two foliar spray of 10 % cow urine and vermiwash at 30 and 50 DAS) and Integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources (natural/organic pesticides for pest management).

3.2.3 Seed siliqua^{-1}

The data observed on seed siliqua^{-1} are presented in Table 4. It was observed that different treatments significantly influenced seed siliqua^{-1}. Significantly higher number of seeds siliqua-1 (18.47, 17.61 and 18.04) during 2022-23, 2023-24 and on pooled basis, respectively were obtained under conventional management Practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O application which was statistically at par with Integrated crop management *i.e.* 50 % RDN through organic + 50 % RDN through inorganic sources and use of need based

Table 2. Effect of different management practices on Yield attributes of wheat under different treatment

	Treatment	Yield Attributes											
		Effective tillers m^{-2}			Earhead length (cm)			Grains $Earhead^{-1}$			Test weight (g)		
		2022-23	2023-24	Pooled	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)	165.1	167.7	166.4	5.85	5.96	5.90	15.55	15.74	15.65	38.65	39.24	38.95
T_2	Complete Natural Farming Practices	178.2	180.3	179.2	6.58	6.73	6.65	18.80	19.32	19.06	39.16	39.66	39.41
T_3	Organic Management Practices	191.4	193.3	192.3	6.92	7.03	6.98	21.15	21.38	21.26	39.94	40.44	40.19
T_4	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural pesticides)	196.2	198.5	197.3	7.06	7.13	7.09	24.73	24.37	24.55	40.10	40.85	40.48
T_5	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + need based pesticides)	204.3	205.2	204.7	7.80	7.90	7.85	27.84	28.43	28.13	41.42	40.92	41.17
T_6	Conventional Management Practices	210.4	211.8	211.1	7.97	8.03	8.00	28.58	28.58	28.58	40.78	41.03	40.90
	Sem+_	2.3	2.0	1.5	0.13	0.23	0.13	0.86	1.26	0.76	0.64	0.54	0.42
	CD (P=0.05)	6.8	6.1	4.4	0.39	0.68	0.38	2.58	3.81	2.20	NS	NS	NS

Table 3. Effect of different management practices on yield of wheat under different treatment

	Treatment	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
		2022- 23	**2023-24**	**Pooled**	**2022-23**	**2023-24**	**Pooled**
T_1	Control (Excluding all inputs except labour for weeding)	1112	1246	1179	1903	2368	2135
T_2	Complete Natural Farming Practices	1364	1552	1458	2336	3265	2800
T_3	Organic Management Practices	2122	2253	2187	3632	3898	3765
T_4	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural pesticides)	2528	2620	2574	4328	4166	4247
T_5	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + need based pesticides)	3016	3083	3050	5213	4936	5074
T_6	Conventional Management Practices	3095	3143	3119	5413	5069	5241
	SEm$\pm$	40	38	28	70	92	249
	CD (P=0.05)	122	116	81	211	277	907

Table 4. Effect of different management practices on Yield attributes of mustard under different treatment

	Treatment	Yield Attributes											
		Siliqua plant^{-1}			Length of siliqua (cm)			Seed siliqua^{-1}			Test weight (g)		
		2022-23	2023-24	Pooled	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)	106.2	108.2	107.2	3.48	3.55	3.52	8.74	8.37	8.56	4.09	3.92	4.01
T_2	Complete Natural Farming Practices	113.7	109.7	111.7	3.67	3.75	3.71	11.55	11.83	11.69	4.23	3.93	4.08
T_3	Organic Management Practices	137.6	134.1	135.8	3.86	3.89	3.88	14.58	14.44	14.51	4.32	4.16	4.24
T_4	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural pesticides)	138.5	141.2	139.9	4.31	4.24	4.27	15.91	14.41	15.16	4.32	4.14	4.23
T_5	ICM (50 % nutrient through organic and 50 % nutrient through inorganicsources + need based pesticides)	163.0	161.6	162.3	4.66	4.88	4.77	17.03	16.93	16.98	4.41	4.22	4.31
T_6	Conventional Management Practices	165.0	164.6	164.8	4.91	5.10	5.00	18.47	17.61	18.04	4.39	4.26	4.32
	Sem+_	4.5	3.8	2.9	0.19	0.18	0.13	0.64	1.03	0.60	0.09	0.22	0.12
	CD (P=0.05)	13.5	11.5	8.5	0.56	0.56	0.38	1.93	3.09	1.75	NS	NS	NS

Table 5. Effect of different management practices on yield of mustard under different treatment

	Treatment	Grain yield (kg ha^{-1})			Straw yield (kg ha^{-1})		
		2022- 23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	Control (Excluding all inputs except labour for weeding)	270.00	284.00	277.00	685.60	743.50	714.55
T_2	Complete Natural Farming Practices	329.00	380.35	354.68	836.82	893.50	865.16
T_3	Organic Management Practices	548.00	396.29	472.14	1393.02	1072.50	1232.76
T_4	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural pesticides)	565.00	671.00	618.00	1435.49	1531.75	1483.62
T_5	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + need based pesticides)	1028.00	1010.00	1019.00	2621.34	2488.50	2554.92
T_6	Conventional Management Practices	1079.00	1110.00	1094.50	2893.90	2730.44	2812.17
	SEm$\pm$	23.01	53.04	28.91	97.79	187.06	105.54
	CD (P=0.05)	69.35	159.88	83.49	294.78	563.86	304.82

Table 6. Effect of different management practices on wheat equivalent yield of mustard under different treatment

	Treatment	Grain yield			Stover yield		
		2022- 23	2023-24	Pooled	2022-23	2023-24	Pooled
T_1	Control (Excluding all inputs except labour for weeding)	692.47	705.32	698.89	137.12	148.70	142.91
T_2	Complete Natural Farming Practices	843.79	944.61	894.20	167.36	178.70	173.03
T_3	Organic Management Practices	1405.46	984.19	1194.82	278.60	214.50	246.55
T_4	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + natural pesticides)	1449.06	1666.44	1557.75	287.10	306.35	296.72
T_5	ICM (50 % nutrient through organic and 50 % nutrient through inorganic sources + need based pesticides)	2636.52	2508.35	2572.43	524.27	497.70	510.98
T_6	Conventional Management Practices	2767.32	2756.70	2762.01	578.78	546.09	562.43
	SEm$\pm$	59.01	131.73	72.17	19.56	37.41	21.11
	CD (P=0.05)	177.86	397.07	208.44	58.96	112.77	60.96

**Price of wheat in 2022-23 = Rs.21.25 kg^{-1}, Price of wheat in 2023-24 = Rs. 22.75 kg^{-1}, Price of mustard in 2022-23 = Rs. 54.50 kg^{-1}, Price of mustard in 2023-24 = Rs. 56.50 kg^{-1}*

*** Prevailing market price of produce from complete natural farming (T2) and organic farming (T3) treatment has been 25% higher than the ICM treatment (T4 and T5) and conventional farming (T6) due to premium price of organic produce.*

pesticides for pest management, while the lowest (8.74, 8.37 and 8.56) recorded in control treatment followed by complete natural farming, AI-NPOF package (75% RDN through organic sources + two foliar spray of 10% cow urine and vermiwash at 30 and 50 DAS) and Integrated crop management *i.e.* 50% RDN through organic and 50% RDN through inorganic sources along with natural/organic pesticides for pest management.

3.2.4 Test weight (g)

Data regarding test weight are presented in Table 4. The finding revealed that different treatment did not affect the test weight significantly during investigation in both the years and on pooled basis. In year 2022-23, highest test weight (4.41g) was recorded under Integrated crop management *i.e.* 50 % RDN through organic + 50 % RDN through inorganic sources and use of need based pesticides for pest management, while in Year 2023-24 and on pooled basis highest test weight (4.26 and 4.32 g respectively) were recorded under conventional farming practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O). Lowest test weight was found under control treatment. (4.09, 3.92 and 4.01g) during both the years and on pooled basis, respectively. However, all the treatment was found at par among each other.

3.2.5 Grain yield (kg ha^{-1})

Data related to grain yield of mustard are presented in Table 5. During both the years and on pooled basis grain yield of mustard was significantly influenced due to natural farming, organic farming, integrated crop management and conventional farming practices.

Among the different treatments, highest grain yield (1079.00, 1110.00 and 1094.50 kg ha^{-1}) was recorded under conventional farming practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O) during 2022-23, 2023-24 and on pooled basis, respectively which was statistically at par with 50 % RDN through organic + 50 % RDN through inorganic sources (need based pesticides for pest management). However the lowest grain yield 270.00, 284.00and 277.00kg ha^{-1}) was recorded in control treatment during both the years and on pooled basis, respectively followed by complete natural farming, AI-NPOF package (75 % RDN through organic sources + two foliar spray of 10 % cow urine and vermiwash at 30 and 50 DAS) and Integrated crop management *i.e.* 50 % RDN through organic and 50 % RDN through inorganic sources (natural/organic pesticides for pest management).

3.2.6 Straw yield (kg ha^{-1})

The data regarding straw yield of mustard are presented in Table 5. Significantly the highest straw yield (2893.90, 2730.44 and 2812.17kg ha^{-1}) was recorded under under conventional farming practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O) during during both the years and on pooled basis, respectively which was statistically at par with 50% RDN through organic + 50% RDN through inorganic sources along with need based pesticides for pest management. However, the lowest straw yield (685.60, 743.50and 714.55 kg ha^{-1}) was recorded in control treatment during both the years and on pooled basis, respectively.

3.3 Wheat Equivalent Yield

The wheat equivalent yield was significantly influenced by different treatments are presented in Table 6.

Among the different treatments, conventional management practices *i.e.* RDN 120:60:40 Kg ha^{-1} N: P_2O_5: K_2O produced significantly higher wheat equivalent yield of mustard (2767.32, 2756.70 and 2762.01 kg ha^{-1}) during 2022-23, 2023-24 and on pooled basis, respectively which was at par (2636.52, 2508.35 and 2572.43 kg ha^{-1}) with integrated crop management *i.e.* 50 % nutrient through organic and 50 % nutrient through inorganic sources (need based pesticides for pest management). However, the lowest wheat equivalent yield of mustard was produced under control treatment (692.47, 705.32 and 698.89 kg ha^{-1}) during 2022-23, 2023-24 and on pooled basis, respectively.

4. DISCUSSION

The finding on yield and yield attributes of wheat + mustard intercropping system as influenced by to natural farming, organic farming, integrated crop management and conventional management practices revealed that conventional management practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O) , integrated crop management *i.e.* 50 % RDN through organic + 50 % RDN through inorganic sources (need based pesticides for pest management), Integrated crop management *i.e*. 50% RDN through organic and 50 % RDN through inorganic sources along with natural/organic pesticides for pest management recorded higher yield attributes and yield as compared to rest of the treatments. Maximum yield found in conventional management practices due to synthetic fertilizer provide consistent and abundant nutrient supply in readily form to meet their physiological demands without delay, which is crucial in high yield production, integrated crop management may be due to the fact that inorganic fertilizers release nutrients for the plants instantly and in readily available forms for the plants during its growth, development and reproductive phase where the nutrient demand is at its peak. Increased yield in INM due to immediate availability of nutrients through inorganic fertilizers along with organic manures ascribed to conductive physical environment that lead to higher nutrient absorption from the native as well as applied sources. This favoured highest nutrient uptake and ultimately resulted in higher yield.

Organic manures improved soil physical, chemical and biological properties and had synergistic relationship with nitrogen and phosphorus thereby mineralization of applied nitrogen and phosphorus helped in increasing growth, increased organic matter content in soil including the humic substance that affected the nutrient accumulation and promoted root growth which led to better growth and ultimately yield attributes and yield of crop. (Tiwari et al. 2024).

Combined application of organic manures and chemical fertilizers played vital role in decomposition and easy release of nutrients and their uptake by crop which leads to higher dry accumulation and its transport in different parts of plant which in turn resulted in higher grain yield. These results are in close agreement with the findings of (Saharan et al. (2023), Verma et al. (2018), Togas et al. (2017) and Borse et al. (2019).

Conventional management practices resulted in the highest yield attributes and productivity in wheat + mustard intercropping system, due to optimal and immediate nutrient availability, ensuring efficient crop growth and development, along with effective pest management. These factors minimized resources competition and maximized the wheat equivalent yield, outperforming natural, organic and integrated crop management practices. Result showed that effective tillers m^{-2}, earhead length, grain $earhead^{-1}$, test weight of wheat higher under Conventional management practices. Similar findings have been reported by Mavi et al. (2004), Barthwal et al, (2013), Chaturvedi et al. (2006) and Khan et al, (2008). Higher wheat grain yield and straw yield with Conventional management practices treatment similar finding Ravankar et al, (2005), Mukherjee (2008) and Malghani et al. (2010). In mustard siliqua $plant^{-1}$, length of siliqua, seed $siliqua^{-1}$ grain yield and stover yield was noted under conventional management practices *i.e.* RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O). these outcomes in line with the findings reported by Ghuman et al. (2021), Ati et al. (2016), Pandey et al. (2009) and Khan et al. (2007).

5. CONCLUSION

The finding clearly reported that conventional management practices i.e. RDN @120:60:40 Kg ha^{-1} of N: P2O5: K2O showed the maximum yield attributes and yield of wheat + mustard intercropping system which was followed by rest of the treatments except control; during 2022-23, 2023-24 and on pooled basis. Highest wheat equivalent yield was recorded under conventional management practices during both years and pooled basis.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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Peer-review history:
The peer review history for this paper can be accessed here:
https://pr.sdiarticle5.com/review-history/130687