Changes in micronutrients and organic matter of soil through integrated nutrient management in Maize-Mustard crop rotation under rainfed agriculture in foothills of Himalayas.

ABSTRACT

Aims: The purpose of this research is to investigate the effects of inorganic and organic fertilizers on availability of micronutrients and organic matter in soils of rainfed areas.

Place and duration of study: Advance Centre for Rainfed Agriculture (ACRA), Rakh Dhiansar, Jammu. Time period 2020-22.

Methodology: In a long-term field experiment, we investigated the effects of 10 treatments on soil micronutrients, organic matter and their correlation under rain fed agriculture. Randomized block design was used with three replications. Following are the treatments: T_1 - Control, T_2 - 100% RDF of N,P,K through chemicals, T_3 - 50% RDF of N,P,K through chemicals, T_4- 50% RD of N through crop residue, T_5 - 50% RD of N through FYM, T_6 -50% RDF of N,P,K through chemicals + 50% RDF of N through crop residues, T_7- 50% RDF of N,P,K through chemicals + 50% RD of N through FYM, T_8 - FYM @ 10 ton/ha, T_9 - 100% RDF of N,P,K through chemicals + Zinc Sulphate @ 20kg/ha and T_{10} - Farmer practice (FYM @ 4 ton/ha + 40kg urea /ha).

The micronutrients Fe, Zn, Cu and Mn showed maximum increase with the application of organic manures along with inorganic fertilizers over control in both surface and sub surface layers of the soil. However, in the sub-surface soil, there was less availability of these nutrients than the surface layer of the soil. The available Zn content was found maximum in the treatment T_9 getting 100% NPK + $ZnSO_4$ @ 20kg/ha over control. The treatment T_8 with the application of FYM @ 10 ton/ha recorded highest content of soil organic matter in surface soil. Positive and significant correlations were observed between soil organic matter and the micronutrient content of the soil. The INM practices proved very beneficial for increasing the sustainability of soil.

Keywords: Rainfed agriculture, INM, soil fertility, micronutrients and organic matter.

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1. INTRODUCTION

Maize (Zea mays L.) is one of the most adaptable developing crops, able to thrive in a wide range of agro-climatic conditions. After rice and wheat, it is the third most significant cereal in India. It plays an essential role in global agriculture as a source of food and fodder, as well as in agro-industries. In 1950-51, India produced 1.73 million metric tonnes of maize, which has climbed to 27.8 million metric tonnes in 2018-19, an almost 16-fold increase in production. In India, maize makes up almost 9% of the country's food supply (Anonymous.,2018). On the other hand, Indian mustard is the country's most important oilseed crop. Mustard productivity in J&K is 6.98 qha^{-1}. It accounts for 23% of total oilseeds area and 23% of the total oilseeds production of the country. Chemical fertilizers plays very important role in increasing the production of mustard but their imbalance use reduce the soil quality and productivity. Both crops are highly nutrient requiring and heavily deplete soil nutrients and moisture. Multiple nutritional deficits arise as a result of poor recycling of organic sources (Kumar., 2008).

Long term sustainability of agriculture is a matter of today's agriculture. Imbalance use of inorganic fertilisers and lack of organic fertilization are the related causal factors for decline of soil properties (Beshir and Abdulkerim, 2017). In order to boost and maintain crop yield and sustainability, there is a need for effective and efficient techniques to halt the process of nutrient mining by returning nutrients to the soil. Integrated nutrient management (INM) is an age-old method of supplying secondary and micronutrients in addition to basic nutrients to meet crop nutrient requirements through organic sources. In addition to having a positive influence on soil health, INM is effective in restoring and maintaining soil fertility, crop yield, preventing primary, secondary and micronutrient deficiencies, improving nutrient use-efficiency and economizing fertiliser use (Singh, Dwivedi and Datta., 2012). To increase N usage efficiency, soil organic carbon, crop production, and soil health, integrated nutrient management strategies entails the use of

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green manure (GM), crop residues, farmyard manure (FYM) and bio-fertilizers are proposed (Liu et al. 2005). But in case of rainfed area and semi arid area in which agriculture is totally dependent on rainfall, integrated nutrient management take a longer period of time to show its effect on fertility of soil. It may be due to harsh conditions of these areas. But it shows positive effect on improvement in soil fertility and crop productivity in these areas also.

In the past, fertilizer research in our country was mostly focused on the nutritional needs of specific crops, but there has recently been a shift in research priorities from individual crops to cropping systems that incorporate residual effects. The addition of inorganic with organic materials speeds up the mineralization process by lowering the C:N ratio. Organic manure releases nutrients slowly and steadily, resulting in fewer losses and higher nutrient use efficiency, whereas inorganic fertilizer releases nutrients quickly, resulting in more losses and poorer fertilizer use efficiency. In light of this, the overall goal of this research was to find the best integrated nutrient management strategies for the rainfed area of Jammu in maize-mustard crop rotation.

2. MATERIALS AND METHODS

The trail region was in the Shiwalik foothills of Jammu and Kashmir at 32°39' North latitude and 74°53' East longitude. with an elevation of 332 m above mean sea level, it is a sub-tropical rainfed area. The field experiment was conducted at of Sher-e-Kashmir University of Agricultural Sciences and Technology (SKUAST), Jammu’s Advance Centre for Rainfed Agriculture (ACRA), Rakh Dhiansar. The soil in the experimental region is alluvial with a sandy loam texture. In terms of soil taxonomy, the soil in the experimental region belongs to entisols order. In reaction, it is mildy acidic to neutral. The climatic conditions of the test site were sub-tropical in nature. The first summer is dry and hot, followed by a humid, hot monsoon and cold winter. The average low and high temperatures show significant fluctuations during the summer and winter seasons. During the months of May and June, temperatures often rise to 45 ° C and lower to 2 ° C at least in December and January winter. The average annual rainfall is between 1050 and 1115 mm, with about

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75% dropping between June and September. Total rainfall and its distribution, on the other hand, vary widely.

The experiment was laid out in randomized block design with three replications. There were ten treatments used in this experiment which are following: T_1 - Control, T_2 - 100% RDF of N,P,K through chemicals, T_3 - 50% RDF of N,P,K through chemicals, T_4- 50% RD of N through crop residue, T_5 - 50% RD of N through FYM, T_6 -50% RDF of N,P,K through chemicals + 50% RDF of N through crop residues, T_7- 50% RDF of N,P,K through chemicals + 50% RD of N through FYM, T_8 - FYM @ 10 ton/ha, T_9 - 100% RDF of N,P,K through chemicals + Zinc Sulphate @ 20kg/ha and T_{10} - Farmer practice (FYM @ 4 ton/ha + 40kg urea /ha). The plot size was 5m x 3m and replicated three times. All agricultural management practices were followed during the growing season for both maize and mustard crops. The application of RDF fertilizer is done on each plant in rotation. The application of half the amount of nitrogen and the full amount of P and K fertilizer is done during sowing of maize and mustard. The remaining amount of nitrogen was used as a top dressing for both plants. FYM @ 10 t ha^{-1} was applied before 15 days of sowing in the ground. After harvesting, the maize stalks were removed from the field to facilitate the planting of the next mustard crop. After the completion of the rotation of maize and mustard crops, soil samples were taken at two depths of 0-15cm and 15-30cm in small polythene bags. These samples were then analyzed to determine chemical properties of soil.

2.1 METHODS EMPLOYED FOR ANALYSIS

Micronutrients were determined in the soil samples of experimental field by atomic absorption spectrophotometer method after extraction by DTPA (Lindsay and Norvell, 1978). Different wavelengths were used for estimation of different micronutrients. Soil organic matter is calculated by estimating the soil organic carbon by the method of walkley and Black, 1934.

3. RESULTS

3.1 AVAILABLE IRON

The various treatments of INM had made significant changes in the status of available iron in the surface layer(0-15cm) of soil after harvest of mustard crop as shown in the table 1.

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The highest value of available iron(20.73 µg g^{-1}) was obtained with the application of 50% RDF of N,P,K through chemicals + 50% RD of N through FYM(T_7). It was at par with the treatments T_6(20.33 µg g^{-1}) receiving 50% RDF of N,P,K through chemicals + 50% RD of N through crop residues) and T_8(19.50 µg g^{-1}) receiving FYM @ 10 ton/ha. Substitution of 50% RD of N through crop residue in treatment T_4 and 50% RD of N through FYM in treatment T_5 were found to be at par with each other but these treatments recorded significantly superior values of available iron over treatments T_2(16.03 µg g^{-1}) and T_9(16.20 µg g^{-1}) in which only chemical fertilizers were used. The lowest available iron (13.43 µg g^{-1}) was recorded in treatment T_1(control) which was found to be statistically at par with treatment T_3(15.70 µg g^{-1}) receiving 50% RDF of N,P,K through chemicals.

In the sub-surface layer(15-30cm) of soil, the available iron at harvest of mustard crop was on the lower side as compared to surface layer(0-15cm) of soil in all the treatments but the trend was similar in both the layers (Table 1).

3.2 AVAILABLE ZINC

At harvest of mustard crop, significant changes in the available zinc content were observed in the soil as shown in the table 1. Available zinc status of surface soil under all the treatments remained above it's critical level in soil. In the surface layer(0-15cm) of soil, the treatment T_9(100% RDF of N,P,K through chemicals + Zinc Sulphate @ 20 kg/ha) had recorded greatest value of available zinc(1.37 µg g^{-1})among all the treatments. It was at par with treatments T_6(1.24 µg g^{-1}) comprising of 50% RDF of N,P,K through chemicals + 50% RD of N through crop residues and T_8(1.25 µg g^{-1}) comprising of FYM @ 10 ton/ha. Addition of 50% of N through organic amendments(crop residues or FYM) in treatments T_4 and T_5 recorded superior values of available zinc (1.16 µg g^{-1}) and (1.04 µg g^{-1}), respectively over the treatments T_2(0.97 µg g^{-1}) and T_3(0.94 µg g^{-1}) in which only chemical fertilizers were applied. The lowest value of available zinc(0.90 µg g^{-1}) was recorded in treatment T_1(control).

In the sub-surface layer(15-30cm) of soil, the available zinc showed same trend as in the surface layer(0-15cm) but the values were lower as compared to surface layer(0-15cm).The status of available zinc in the sub-surface layer(15-30cm) of soil in treatments T_1, $T_2$and

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T_3 was below critical level where as in all other treatments it was above critical level. In the sub-surface layer(15-30cm), the available zinc declined as compared to surface layer of soil.

3.3 AVAILABLE COPPER

Data depicted in table 2 revealed significant effect of various treatments of INM on the status of available copper in the surface layer(0-15cm) of soil after the harvest of mustard. In the surface layer(0-15cm) of soil, available copper content ranged from 0.66 μg g^{-1} to 0.87 μg g^{-1} in various treatments of organic and inorganic fertilizers. The maximum content of available copper(0.87 μg g^{-1}) in soil was observed under the treatment(T_7) receiving 50% RDF of N,P,K through chemicals + 50% RD of N through FYM which was significantly higher than that under control(T_1). However, it(T_7) was at par with all other treatments indicating positive effect of use of organics or inorganics separately or in combination on available Cu in the soil. The lowest available copper content was found in the treatment T_1 in which no nutrient source was applied.

In the sub-surface layer(15-30cm) of soil, same trend was obtained in case of available copper but the values were on lower side as compared to surface layer(0-15cm). In the sub-surface layer(15-30cm), the treatment T_7 had significantly highest available copper(0.78 μg g^{-1}) but it was statistically at par with the treatments T_5(0.59 μg g^{-1}), T_6(0.62 μg g^{-1}) and T_8(0.73 μg g^{-1}).However, the lowest value of available copper(0.39 μg g^{-1}) was recorded in the treatment T_1(control).

3.4 AVAILABLE MANGANESE

Various combination of INM treatments significantly influenced the availability of manganese in the soil(Table 2). The treatment T_8 with the application of FYM @ 10 ton/ha recorded highest content of available manganese(23.37 μg g^{-1}) in surface soil which was statistically at par with the treatments T_7 comprising of 50% RDF of N,P,K through chemicals + 50% RD of N through FYM and T_6 comprising of 50% RDF of N,P,K through chemicals + 50% RD of N through crop residues. The lowest available manganese (12.57 μg g^{-1}) was recorded in treatment T_1(Control) which was found to be at par with the

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treatment T_{10}(15.30 µg g^{-1}) comprising of FYM @ 4 ton/ha + 40kg urea/ha(Farmer practice).

In the sub-surface layer(15-30cm), there was reduction in the available manganese but pattern similar to that obtained in surface layer. In the sub-surface layer(15-30cm) of soil, the maximum available manganese(16.93 µg g^{-1}) was recorded in treatment T_8 which was at par with the treatment T_7(15.73 µg g^{-1}). The lowest available manganese(6.90 µg g^{-1}) was recorded in treatment T_1(Control) which was statistically at par with the treatment T_{10}(8.27 µg g^{-1}) receivingFYM @ 4 ton/ha + 40kg urea /ha(Farmer practice).

3.5 SOIL ORGANIC MATTER

The organic carbon content (table 2) in the surface layer(0-15cm) of soil was improved significantly with the application of different integrated nutrient treatments. In the surface layer(0-15cm) of soil, among all the treatments, the maximum accumulation of organic carbon(4.70 g kg^{-1}) content was observed with the application of FYM @ 10 ton/ha in treatment T_8 which was found to be statistically at par with the treatment T_7(4.1 9g kg^{-1}) receiving 50% RDF of N,P,K through chemicals + 50% RD of N through FYM but superior to rest of the treatments. The treatment T_6 (50% RDF of N,P,K through chemicals + 50% RD of N through crop residues) showed higher build-up of organic carbon(3.58g kg^{-1})as compared to the application of 50% RD of N through crop residue in treatment T_4(2.92g kg^{-1}) and application of 50% RD of N through FYM in treatment T_5(2.41g kg^{-1}). The lowest amount of organic carbon(1.34 g kg^{-1}) was recorded in treatment T_1(control) plot which was statistically at par with the treatment T_2(2.13g kg^{-1}) receiving 100% RDF of N,P,K through chemicals, T_3(1.95g kg^{-1}) receiving 50% RDF of N,P,K through chemicals, T_9(2.21g kg^{-1}) receiving 100% RDF of N,P,K through chemicals + Zinc Sulphate @ 20 kg/ha and T_{10}(1.87g kg^{-1}) receiving FYM @ 4 ton/ha + 40kg urea /ha(Farmer practice).

In the sub-surface layer(15-30cm) of soil, the lower organic carbon content was recorded than that in surface layer(0-15cm), but the trend was same among all the treatments in both the layers of the soil. The highest value of organic carbon (2.98 g kg^{-1}) was recorded in the treatmentT_8 which was at par with the treatments T_6(2.50g kg^{-1}) and T_7(2.66g kg^{-1}). The application of 50% N through crop residue in treatment T_4(2.03g kg^{-1}) and 50% N through through FYM in treatment T_5(1.97g kg^{-1}) showed superior values of organic carbon than that under sole application of 100%

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NPK through chemicals in treatment T_2(2.13g kg^{-1}). The Treatment T_1(control) recorded lowest organic carbon (0.93g kg^{-1}) in sub-surface soil layer.

4. Discussion

4.1 Available iron

The significant changes in available iron were observed under various treatments of INM in the soil. The treatment receiving 50% organic amendments along with 50% inorganic fertilizers recorded highest accumulation of available iron in the surface soil. Addition of organic only recorded higher content of available iron in soil as compared to use of inorganics only. The conjoint application of organic and inorganic sources of nutrients increased available iron, reason that the organic acids that are released during the mineralization of FYM makes organic chelates leading to prevention of adsorption, fixation and precipitation of iron and solubilization of the already precipitated iron in the soil(Selvi *et al.* 2003; Parven *et al.* 2020). Walia *et* al., 2010 also reported maximum increase in available iron with the the incorporation of 100% NPK through chemicals + 50% N through FYM in rice wheat cropping system. Mann *et al.*,(1978) also observed an increase in available iron with the application of FYM only in soil. The lowest available iron(13.43 µg g^{-1}) was recorded under control because there was no addition of nutrient sources and continuous cropping. In the sub-surface layer of soil, the quantity of available iron was low as compared to surface soil. This might be due to the fact that lower accumulation of the SOM in sub-surface soil resulted in less organic chelates. Kher (1993) also noted depth wise reduction in available iron under maize wheat cropping system

4.2 Available zinc

The application of 100% RDF of N,P,K through chemicals along with zinc sulphate @ 20 kg/ha in the treatment T_9 significantly increased the available zinc in the soil over other treatments. Meshram *et al.*,(2016) also reported that the application of 100% NPK with Zn considerably raised the levels of available zinc in the soil. The application of crop residues along with inorganic sources of nutrients in treatment T_6 and only FYM in treatment T_8 also contributed to the increase in zinc content in the soil. This might be due

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to the improvement in zinc mobilization and prevention of fixation of zinc by the process of complexation (Banerjee *et al.* 2011; Walia *et al. 2010*). No any marked difference in the available zinc content in the soil was found in treatments in which only inorganic fertilizers were applied. These results were in line with the findings of Parven *et al.*, (2020). The lowest available zinc was found in the treatment T_1 in which continuous cropping without any addition of fertilizer depleted the available zinc and reduced it's amount from the soil. In the sub-surface layer(15-30cm), the available zinc declined as compared to surface layer of soil. This might be due to low SOM in sub-surface soil resulting in less complexation, less mobilization of zinc but more fixation of zinc in the soil.

Table 1- Long-term effect of INM on available iron and zinc in soil

Treatments	**Available Fe (μg g^{-1})**		**Available Zn (μg g^{-1})**	
	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**
T_1 Control	13.43	12.07	0.90	0.46
T_2 100% RDF of N,P,K through chemicals	16.03	14.27	0.97	0.57
T_3 50% RDF of N,P,K through chemicals	15.70	12.63	0.94	0.53
T_4 50% RD of N through crop residue	17.73	14.87	1.16	0.72
T_5 50% RD of N through FYM	18.50	16.20	1.04	0.67
T_6 50% RDF of N,P,K through chemicals + 50% RD of N through Crop residues	20.33	16.93	1.24	0.89
T_7 50% RDF of N,P,K through chemicals + 50% RD of N through FYM	20.73	18.43	1.21	0.87
T_8 FYM @ 10 ton/ha	19.50	16.70	1.25	0.94
T_9 100% RDF of N,P,K through chemicals + Zinc Sulphate @ 20 kg/ha	16.20	15.27	1.37	0.94
T_{10} Farmer practice (FYM @ 4 ton/ha + 40kg urea /ha)	16.05	14.15	1.02	0.65

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4.3 Available copper

The available copper was significantly influenced under various treatments of integrated nutrient management. The maximum content of available copper in soil was observed under the treatment(T_7) receiving 50% RDF of N,P,K through chemicals + 50% RD of N through FYM which was significantly higher than that under control(T_1).The increase in available copper in T_7 may be ascribed to increase in SOM with the addition of FYM along with chemical fertilizers. As the SOM increases, the organic chelates also increase in the soil that prevents the fixation, precipitation and adsorption of the copper ions and enhances the solubilization of already present copper content in the soil by making it in the available form(Walia *et al.* 2010; Dhaliwal *et al.* 2019; Mali *et al.* 2014). Prasad and Sinha (2000) also observed the positive increase in available copper with the addition of different levels of fertilizers along with organic manures. In the sub-surface layer(15-30cm), the available copper was reduced as compared to surface layer that might be due to the lower SOM at this depth. The lowest SOM led to more fixation and adsorption of copper content in the soil. The findings of Kumar *et al.*, (1996) were in agreement with our results.

4.4 Available manganese

Various combination of INM treatments significantly influenced the availability of manganese in the soil. The treatment T_8 with the application of FYM @ 10 ton/ha recorded highest content of available manganese in soil which was statistically at par with the treatments T_7 comprising of 50% RDF of N,P,K through chemicals + 50% RD of N through FYM and T_6 comprising of 50% RDF of N,P,K through chemicals + 50% RD of N through crop residues. There was no marked difference in available manganese in soil in treatments T_8, T_7 and T_6. The higher available manganese content in soil under these treatments might be due to chelating action of organic manures. During the decomposition of organic manures, many organic acids released reduces the fixation and adsorption of manganese by making complexes with clay and other compounds. Also increased SOM under these treatments help in solubilization of fixed manganese in the soil (Walia *et al.* 2010; Dhaliwal *et al.* 2019; Mali *et al.*2014). Similar results were observed by Lal and Mathur (1989). The lowest available manganese(12.57 µg g^{-1}) in soil was found in the treatment T_1 due to no addition of any organic or inorganic source in the soil. This might be due to less SOM and less complexation process at this depth. These results were in confirmation with the findings of Singh *et al.*, (1990).

Table 2- Long-term effect of INM on available copper and manganese in soil

Treatments	Available Cu (µg g^{-1})		Available Mn (µg g^{-1})		Soil Organic Matter(%)	
	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
T_1 Control	0.66	0.39	12.57	6.90	0.23	0.16
T_2 100% RDF of N,P,K through chemicals	0.73	0.44	17.33	10.37	0.37	0.32
T_3 50% RDF of N,P,K through chemicals	0.73	0.41	15.97	8.67	0.34	0.28
T_4 50% RD of N through crop residue	0.83	0.52	20.20	13.30	0.50	0.35
T_5 50% RD of N through FYM	0.84	0.59	19.76	11.23	0.41	0.34
T_6 50% RDF of N,P,K through chemicals + 50% RD of N through Crop residues	0.84	0.62	22.17	13.73	0.62	0.43
T_7 50% RDF of N,P,K through chemicals + 50% RD of N through FYM	0.87	0.78	22.40	15.73	0.72	0.46
T_8 FYM @ 10 ton/ha	0.84	0.73	23.37	16.93	0.81	0.51
T_9 100% RDF of N,P,K through chemicals + Zinc Sulphate @ 20 kg/ha	0.77	0.48	19.10	10.70	0.38	0.33
T_{10} Farmer practice (FYM @ 4 ton/ha + 40kg urea /ha)	0.80	0.50	15.30	8.27	0.32	0.25

4.5 Soil organic matter

Application of FYM alone @ 10ton/ha(T_8) or use of 50% RD of NPK through chemicals and rest of N through crop residues/FYM recorded appreciable increase in O.C as compared to all other treatments. The maximum accumulation of O.C was observed in treatment T_8 receiving FYM@ 10ton/ha which was significantly higher as compared to rest of treatments except T_7 receiving 50% RDF of NPK through chemicals along with 50% N through FYM. The decomposition and mineralization of organic manures induced higher accumulation of SOC(Walia *et al.* 2010; Prakash *et al.* 2007; Das *et al.* 2016). Bhattacharyya *et al.*, 2010 also reported that the soil treated with FYM+NPK recorded higher organic carbon over the soil treated with NPK alone. Similar results were also reported by Hati *et al.*, (2006). The lowest SOC was observed in the treatment T_1 control which might be due to continuous cropping without any addition of organic manures that results in the depletion of SOC(Manna *et al.*, 2006). In the sub-surface layer(15-30cm), the SOC content decreases but the pattern was similar as in the surface layer. The lower SOC in the sub-surface layer might be due to less SOM as compared to surface layer of soil. These results were in agreement with the findings of Ghosh *et al.*, (2017).

5. RELATIONSHIP STATUS BETWEEN SOIL PROPERTIES AND SOIL ORGANIC MATTER

In both the surface and sub-surface layers of soil, a positive and significant correlation was found between the micronutrients Fe(Fig. 1), Zn(Fig. 2), Cu(Fig. 3) and Mn(Fig. 4) and soil organic matter. Bhatt *et al*., (2017) also reported the same findings in his study.

Fig. 1 Relationship between soil organic matter and available iron in surface and sub-surface layer of soil

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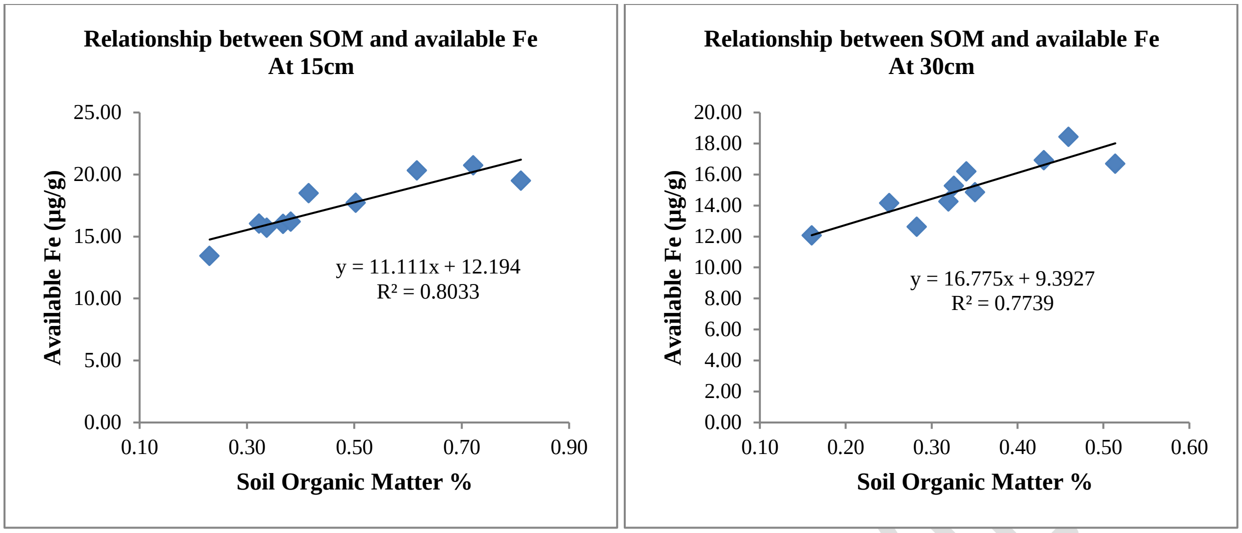


Fig. 2 Relationship between soil organic matter and available zinc in surface and sub-surface layer of soil

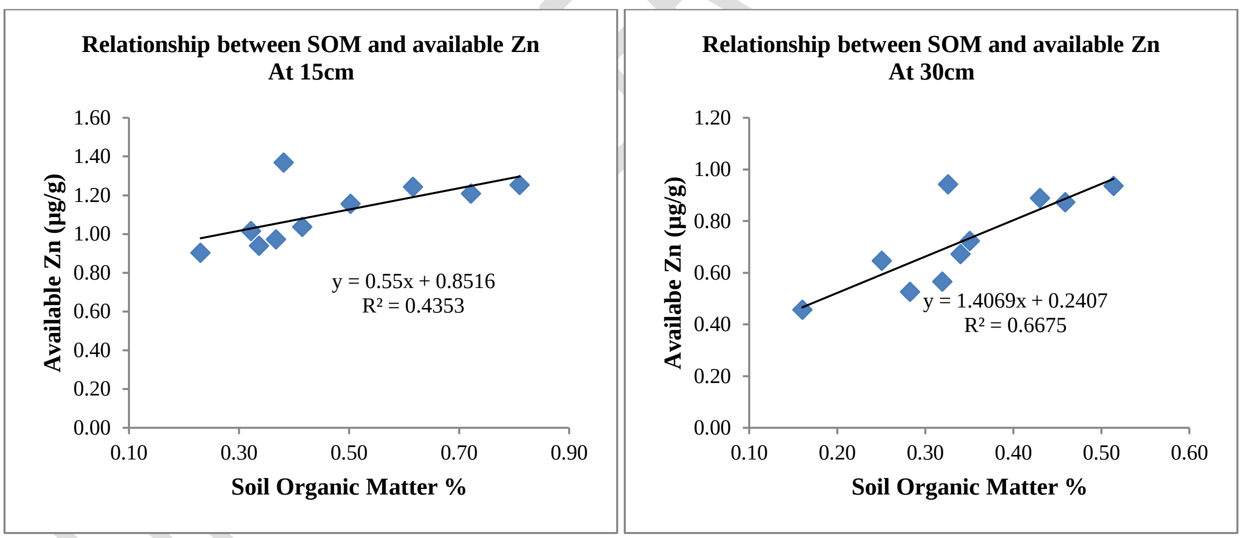


Fig. 3 Relationship between soil organic matter and available copper in surface and sub- surface layer of soil

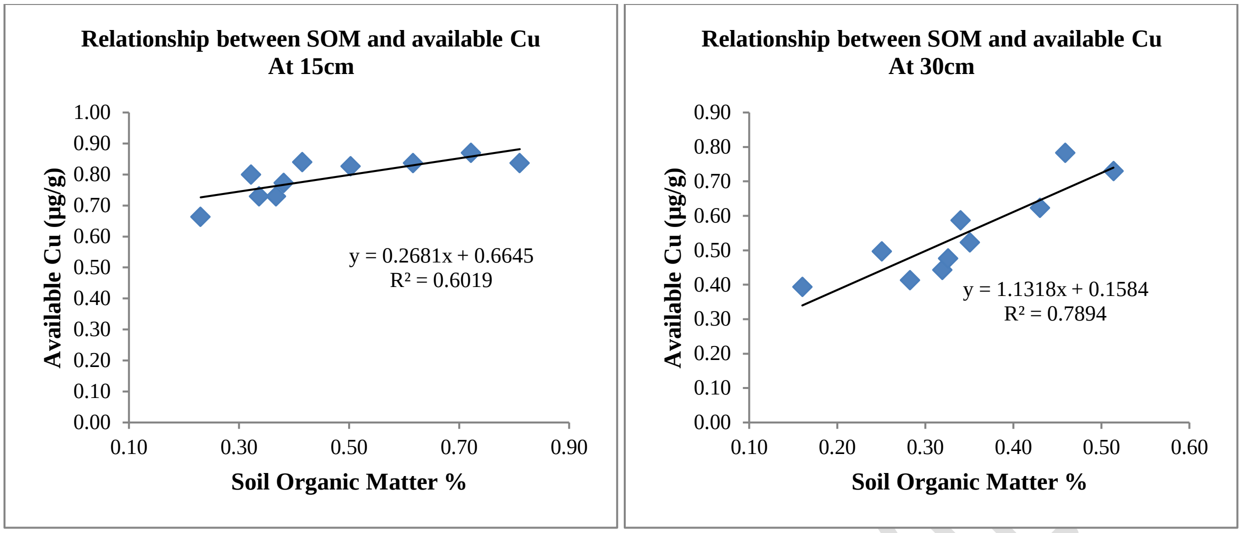
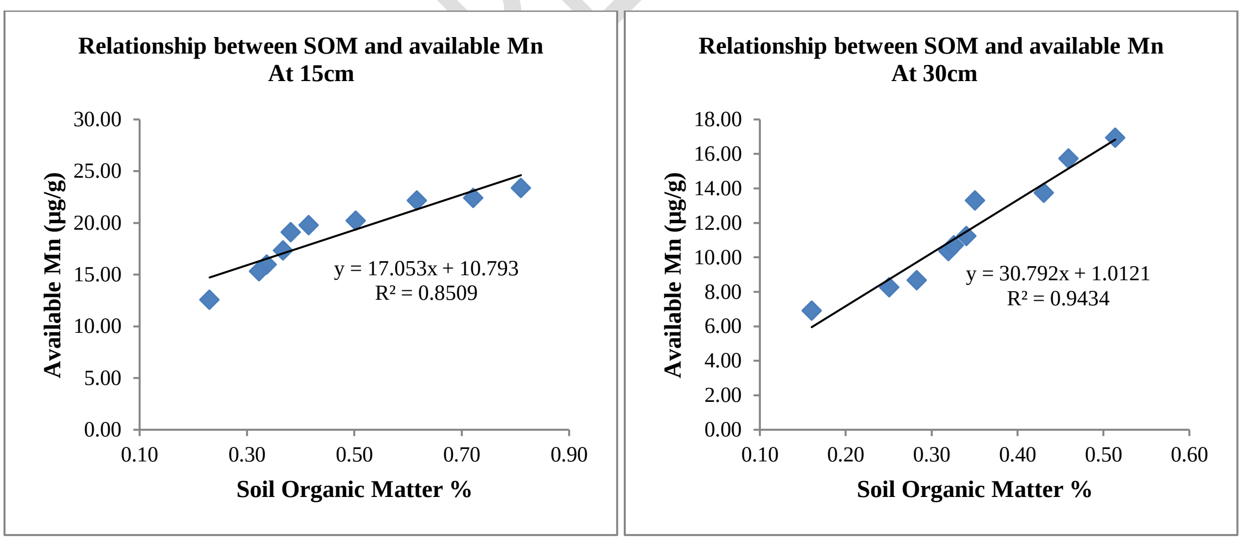


Fig. 4 Relationship between soil organic matter and available manganese in surface and sub- surface layer of soil



6. CONCLUSION

From the investigation, it is concluded that the long term INM practices shows great potential in increasing the fertility of the soil in rainfed areas. The addition of different treatments of INM enhanced the chemical properties of the soil. The availability of micro(Fe, Zn, Cu, Mn) nutrients and soil organic matter increased with the substitution of only organic manures or conjointly with inorganic fertilizers in both surface and sub surface layers of soil over control. However, in the subsurface soil, there was less improvement in chemical properties as compared to the surface layer of the soil. This might be due to less accumulation of SOM in the sub-surface layer than the surface layer. The maximum increase in available zinc was found with the application of zinc sulphate @20kg/ha along with 100% NPK in the soil. Positive and significant correlations were observed between soil organic matter and the nutrient content of the soil. Thus, this study signified that the integrated use of chemical fertilizers and manures are ecological important for increasing the soil sustainability and fertility in maize mustard crop rotation under rainfed agriculture.

REFERENCES

1. Anonymous. 2018. Indian institute of maize research.
2. Banerjee, A., Datta, J. K., Mondal, N.K. and Chanda, T. 2011. Influence of integrated nutrient management on soil properties of old alluvial soil under mustard cropping system. *Communications in Soil Science and Plant Analysis.* **42**: 2473-2492.
3. Beshir, S. and Abdulkerim, J. 2017. Effect of maize/haricot bean intercropping on soil fertility improvement under different tied ridges and planting methods, southeast Ethiopia. *Journal of Geoscience and Environment Protection*. **5** (8):63–70.
4. Bhat, M. A., M. S. Grewal, I. S. Dinesh, and K. S. Grewal. 2017. Geoinformatics for quantifying salt affected soils in Gohana, Haryana using soil techniques. International Journal of Current Microbiology and Applied Sciences 6 (9):835–58.
5. Bhattacharyya, R., Kundu, S., Srivastva, A. K., Gupta, H.S., Prakash, V. and Bhatt, J.C. 2010.

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6. Long term fertilization effects on soil organic carbon pools in a sandy loam soil of the Indian sub-Himalayas. *Plant Soil.* **341**:109–124.
7. Das, D., Dwivedi, B.S., Singh, V.K., Datta, S.P., Meena, M.C., Chakraborty, D.,Bandyopadhyay, K.K., Kumar, R., Mishra, R.P., 2016. Long term effects of fertilisers and organic sources on soil organic carbon fractions under rice-wheat system in the Indo-gangetic plains of northwest India. *Soil Research.*
8. Dhaliwal, S. S., Naresh, R. K., Mandal, A., Walia, M. K., Gupta, R.K., Singh, R. & Dhaliwal, M. K. 2019. Effect of manures and fertilizers on soil physical properties, build-up of macro and micronutrients and uptake in soil under different cropping systems. *Journal of Plant Nutrition.***42** (20): 2873-2900.
9. Ghosh, A., Bhattacharyya, R., Meena, M. C., Dwivedi, B. S., Singh, G., Agnihotri, R., &
10. Sharma, C. 2017. Long-term fertilization effects on soil organic carbon sequestration in an Inceptisol. Soil & Tillage Research. **177**: 134–144.
11. Hati, K.M., Swarup, A., Singh, D., Misra, A.K., and Ghosh, P.K. 2006.Long-term continuous cropping, fertilisation, and manuring effects on physical properties and organic carbon content of a sandy loam soil. *Australian Journal of Soil Research*. **44**: 487–495.
12. Kher, D. 1993. Effect of continuous liming, manuring and cropping on DTPA-extractable micronutrients in an Alfisol. *Journal of Indian Society of Soil Sciences.* **41**:366–7.
13. Kumar, A. 2008. Direct and residual effect of nutrient management in maize (Zea mays)–wheat (Triticum aestivum) cropping system. *Indian Journal of Agronomy*. **53** (1):37–41.
14. Kumar, T. V., Reddy, M. S. and Krishna, V.G. 1996. Vertical distribution of micronutrient cations in some soil profiles in northern Telangana of Andhra Pradesh. *Journal of Indian Society of Soil Sciences.* **44**:328
15. Lal, S. and Mathur, B. S. 1989. Effect of long term application of manure and fertilizer on DTPA-extractable micronutrients in acid soils. *Journal of the Indian Society of Soil Science*. **37**:588–590.
16. Liu, X., Liu, J., Xing, B., Herbert, S.J., Meng, K., Han, X. and Zhang, X. 2005. Effects of long term continuous cropping, tillage, and fertilization on soil organic
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Carbon and Nitrogen of black soils in China. *Communications in Soil Science and Plant Analysis*. **36** (9–10):1229–39.

17. Mali, D.V., Kharche, V.K., Jadhao, S.D., Deshmukh, P.W., Saoji, B.V and Mohod, P. V. 2014. Soil physical propertiesunder long term use of organics inconjunction with chemical fertilizers in a sorghum-wheatcroppingsequence in Inceptisol. *Journal of Agriculture Research and Technology*. pp: 12-17.
18. Mann, M.S., Takkar, P. N., Bansal, R. L., and Randhawa, N. S. 1978. Micronutrient status of soil and yield of maize and wheat as influenced by micronutrient and FYM application. *Journal of the Indian Society of Soil Science*. **26**:208–214.
19. Manna, M.C., Swarup, A., Wanjari, R,H., Singh, Y.V., Ghosh, P.K., Singh, K.N., Tripathi, A.K., Saha, M.N. 2006. Soil organic matter in a West Bengal inceptisol after 30 years of multiple cropping and fertilization. *Soil Science Society Journal*. **70**:121–129
20. Meshram, N.A., Ismail, S., Shirale, S.T. and Patil, V.D. 2016. Impact of Long-term fertilizer application on soil fertility, nutrient uptake, growth and productivity of soybean under soybean-safflower cropping sequence in Vertisol. *Legume Research-An International Journal*. **42** (2):182-189.
21. Parven, H., Kumar, S., Shambhavi, S., Kumar, S., Kumar, R. And Kumari, D. 2020. Long Term Effect of integrated nutrient management on secondary and micronutrient of Alluvial soils. *International Journal of Current Microbiology and Applied Sciences.* **9**(2):1990-1999.
22. Prakash, V., Bhattacharyya, R., Selvakumar, G., Kundu, S., Gupta, H. S. 2007. Long-term effects of fertilization on some soil properties under rainfed soybean-wheat cropping in the Indian Himalayas. *J. Plant Nutr. Soil Sci*. **170**:224–233.
23. Prasad, B. and Sinha, S.K. 2000. Long-term effects of fertilizers and organic manures on crop yields, nutrient balance and soil properties in rice-wheat cropping system in Bihar. Rice -Wheat Consortium Paper Series 6. New Delhi, India: Rice-Wheat Consortium for the Indo-Gangetic Plains .pp: 105-119.
24. Selvi, D., Mahimairaja, S., Santhy, P. and Rajkannam, B. 2003. Effect of organic and inorganic P fertilizers on sustainability of soil fertility and grain yield in a rice-pulse system. *International Rice Research Notes.* **28**:41–3.

UNDER PEER REVIEW

25. Singh, K., Goyal, V.P. and Singh, M. 1990. Distribution of micronutrient cations in semi-arid alluvial soil profiles. *Journal of Indian Society of Soil Science*. **38**:736–7.
26. Singh, M., Dwivedi, B.S. and Datta, S.P. 2012. Integrated nutrient management for enhancing productivity, nutrient use efficiency and environmental quality. New Delhi: In soil science in the service of nation, ISSS.
27. Walia, M.K., Walia, S.S. and Dhaliwal, S.S. 2010. Long-term effect of integrated nutrient management of properties of Typic Ustochrept after 23 cycles of an irrigated rice – wheat system. *Journal of Sustainable Agriculture*. **34**:724–743.
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