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ORIGINAL ARTICLE **OPEN ACCESS**

Residual effect of INM on succeeding Maize crop in Mentha–Maize rotation

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ABSTRACT
Field experiment was conducted to comprise the different levels of inorganic and inorganic fertilizers with Trichoderma viride on growth and yield of mentha (Mentha arvensis) and residual effects on Maize crop in mentha- maize cropping system. Trial was conducted at Rampur Maniharan, Saharanpur in Randomized Block Design with nine treatments and replicated three times for two consecutive years. Different doses of NPK (inorganic) and Farm Yard Manure (FYM) were combined with T. viride which was applied in preceding Mentha crop. In this investigation, different treatments had favorable influence on the yield attributing characters (plant height, grains/cob, test weight and green cob). Conjoint use of 12.5 t FYM and NPK fertilizer produced the taller plants. Grain and stover yield of maize significantly increased due to application of nutrients in preceding crop. The treatments T_5, T_7, T_8 and T_9 were at par in respect of grain and stover production. The content and yield of protein increased significantly with NPK fertilizers addition in preceding mentha crop. The content and uptake of N, P and K in maize crop increased significantly with the application of Trichoderma viride along with NPK and FYM slightly enhanced in both the years. FYM and NPK fertilizer application alone. The content and yield of protein were maximum under T_7 (T_7 N_{50}+ P_{25}+ K_{25} + 12.5 t FYM + Trichoderma .v) treatment. Application of FYM in combination with NPK fertilizers in preceding mentha crop also enhanced the content and uptake of Fe & Zn significantly over control. The maximum content and uptake values were recorded under T_5 treatment. Soil pH, EC and organic carbon content in soil were not affected significantly with various treatments applied in preceding crop. However, the higher values of organic carbon content were noted in soil treated with FYM. Available NPK status of the soil improved with NPK fertilizers and FYM over control. Application of FYM with NPK levels improved the build of available zinc and iron in soil.
Keywords: *Mentha arvensis, Integrated Nutrient Management, T. viride , Maize*

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INTRODUCTION

Mentha is a small genus of aromatic perennial herbs belonging to family Labiatae (Lamiaceae), distributed mostly in temperate and sub- temperate region of the world. On account of being the natural source of menthol, the essential oil of *Mentha arvensis* finds extensive uses in a wide range of cosmetic and pharmaceutical preparations. Looking at the increasing demand of menthol in pharmaceuticals and cosmetic industries at home and abroad, it has become imperative to boost up its production through low cost on farm inputs like use of organic manure and recycling of wastes [9]. Maize (*Zea mays L*) is also an important crop as a source of food and maize straw used as livestock feed in India which is grown for fodder and grain purpose.

The growing conditions of Mentha in the cropping system provide the best opportunity for immediate incorporation and further decomposition of organic manure as well as the distillation waste in situ for succeeding crop. The distillation waste which retains its nutritional value even after extraction of essential oil can be recycled to supplement the nutritional requirement of crop(s) to follow and to restore soil fertility. Pathak *et al.* [8] reported that all the treatments produced significantly higher yield in comparison to control in both the crops during both the years. The yield of groundnut was highest (12.37

q ha^{-1}) with N_{30} P_{60} K_{30} in first year. However, during second year FYM (6.0 t ha^{-1}) gave the highest yield of (13.98 q ha^{-1}). In case of wheat, the residual effect of FYM (6.0 t ha^{-1}) + Rhizobium gave the highest yield of 24.0 and 25.5 q ha^{-1}, respectively. The yield attributing characters were influenced significantly by the various treatments applied through inorganic and organic fertilizers. Increasing levels of NPK fertilizers also improved these characters. The combined application of nitrogen + FYM enhanced significantly the yield attributes over control in both years. Singh *et al* [11] found that more number of maize plants m-2 , plant height, 1000-grain weight were noted in plots previously treated with 75 % of RDF + Vermi Compost + Azotobactor which was statistically equal to that of 50 % of RDF + Vermi Compost + Azotobactor followed by 75 % of RDF + Vermi Compost. In addition, application of organic manure or others organic wastes may also generate a positive residual effect that should be taken into account when planning the next crop [2, 4]. However, few scientists have been work for combined used of inorganic and organic fertilizers and its residual impact on succeeding crop.

Keeping in view the above mentioned facts, the present study was conducted with to evaluate the residual effect of fertilizer on yield uptake of nutrient and soil heath in mentha- maize rotation.

MATERIAL AND METHODS

Study Area and chemical properties of soil

Field experiments were conducted at farmers' field at Rampur Maniharan, Saharanpur (U.P.) for two consecutive years to ascertain the effect of integrated nutrient management on yield and oil yield of *Mentha arvensis* in mentha-maize rotation. Saharanpur is an agriculturally important district situated below foot hills of North Himalaya. Experimental soil is a member of Sandy loam. Soil had pH 7.2, EC 0.11 dSm-1,Organic Carbon 4.5 g kg^{-1} , Calcium Carbonate 5.0 g kg^{-1}, KMnO4 -N 190.0 kg ha^{-1}, Olsen' s - P 9.5 kg ha^{-1}, ammonium acetate extractable - K 215.0 Kg ha^{-1} and DTPA Extractable Zn & Fe were 0.60 mg kg^{-1} & 5.0 mg kg^{-1}, respectively.

Treatments

The treatments were : T_1 - Control ,T_2 - 25 t FYM ha^{-1}, T_3 - 12.5 t FYM ha^{-1} + *T. viride*., T_4 - 25 t FYM ha^{-1} + *T. viride*. , T_5 - N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1} , T_6 - N_{50} + P_{25} + K_{25} + *T. viride*., T_7 - N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1} + *T. viride*. , T_8 - N_{100} + P_{50} + K_{50} + *T. viride*. & T_9 - N_{100} + P_{50} + K_{50} .

Experiment Activity

The treatments were imposed in first year with mentha crop as first test crop in the sequence with maize and replicated three times in a randomized block design. After harvest of mentha, pre- sowing irrigation was given and then field was prepared in the second week of June for sowing of maize. Nitrogen was supplied in the form of urea (46% N) as per treatments. Single superphosphate (16% P_2O_5) and muriate of potash (60% K_2O) were used as sources for P_2O_5 and K_2O, respectively. Full quantities of P and K fertilizers were applied at the time of planting. Nitrogen (as per treatments) was applied in two equal splits, the first applied at planting and the remaining after one and half month of planting. Full dose of well-decomposed FYM was applied as per treatments at the time of planting. The seedlings of mentha were treated with *T.viride* culture. The maize crop was grown without any fertilizer application. The seeds of maize variety Vijay were sown in lines at 45 cm apart using the seed rate of 30 kg ha-1 in the month of June in both years. The lines were opened through pointed spade by human labour. After sowing, planking was done to cover the seeds. At harvest of maize crop straw and grain samples were also collected.

RESULTS

Yield attributing characters

Data on yield attributing characters i.e. plant height, weight of green cob, grain weight/cob and test weight) were recorded at harvest and summarized in Table 1.

Table 1: Growth and yield attributes of maize as affected by different treatments

Treatments	Plant height		Grains/cob		Test weight (g)		Weight of green cob (g)	
	I year	II year	I year	II year	I year	II year	I year	II year
T_1control	128.0	129.50	137.0	140.5	140.6	142.7	96.6	98.1
T_2 25t FYM ha^{-1}	142.85	146.45	271.7	274.0	152.7	155.0	150.0	153.2
$T_3$12.5t ha^{-1}+*Trichoderma*	133.35	134.00	255.0	258.1	146.0	148.2	142.8	145.0
T_4 25 t ha^{-1}+*Trichoderma*	145.10	147.35	291.1	293.7	162.5	163.6	160.9	163.7
T_5 N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1}	155.75	157.00	326.0	328.1	173.7	177.1	181.0	182.5
T_6 N_{50} + P_{25}+ K_{25} +*Trichoderma*	135.00	137.50	258.0	260.4	156.0	152.0	148.7	150.0
T_7 N_{50}+ P_{25}+ K_{25} + 12.5 t FYM +*Trichoderma*	156.00	158.00	326.7	328.5	174.5	177.3	182.0	184.0
T_8 N_{100}+ P_{50}+ K_{50} + *Trichoderma*	152.55	155.85	307.0	310.7	172.0	173.9	174.4	177.0
T_9 N_{100}+P_{50}+K_{50}	154.00	156.42	308.0	311.0	175.5	174.2	175.2	177.5
SEm±	1.16	1.21	3.51	4.00	1.21	1.30	1.27	1.31
CD (P=0.05)	3.41	3.56	10.32	11.76	3.53	3.80	3.71	3.82

Grain and stover yield

Table 2 showed the grain and stover yield of maize in both the years.

Table 2: Effect of various treatments on grain and stover yield of maize

Treatment	Grain (qha^{-1})		Stover (qha^{-1})	
	I year	II year	I year	II year
T_1 control	16.20	16.51	44.13	44.82
T_2 25t FYM ha^{-1}	20.55	21.85	60.39	61.20
T_3 12.5t ha^{-1}+*Trichoderma*	18.27	19.95	54.00	55.17
T_4 25 t ha^{-1}+*Trichoderma*	22.10	23.22	59.15	62.45
T_5 N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1}	23.80	25.17	63.07	65.75
T_6 N_{50} + P_{25}+ K_{25} +*Trichoderma*	19.65	20.00	56.75	58.63
T_7 N_{50}+ P_{25}+ K_{25} + 12.5 t FYM +*Trichoderma*	25.40	27.05	65.60	67.00
T_8 N_{100}+ P_{50}+ K_{50} + *Trichoderma*	24.72	25.95	64.60	66.17
T_9 N_{100}+P_{50}+K_{50}	25.50	26.40	65.75	66.90
SEm±	0.73	0.81	0.76	0.91
CD (P=0.05)	2.13	2.36	2.22	2.65

Protein Content and Protein Yield

The values of protein content and protien yield in maize crop were shown respectively in both seasons (Table 3).

Table 3: Effect of various treatments on protein content and protein yield of maize

Treatment	Protein content (%)		Protein yield (kg ha^{-1})	
	I year	II year	I year	II year
T_1control	9.18	9.31	148.71	153.70
T_2 25t FYM ha^{-1}	9.37	9.50	192.55	207.57
$T_3$12.5t ha^{-1}+*Trichoderma*	9.31	9.37	170.09	186.93
T_4 25 t ha^{-1}+*Trichoderma*	9.43	9.50	208.40	220.59
T_5 N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1}	9.62	9.68	228.95	243.64
T_6 N_{50} + P_{25}+ K_{25} +*Trichoderma*	9.50	9.37	186.67	187.40
T_7 N_{50}+ P_{25}+ K_{25} + 12.5 t FYM +*Trichoderma*	9.68	9.75	245.87	263.75
T_8 N_{100}+ P_{50}+ K_{50} + *Trichoderma*	10.00	10.06	247.20	261.05
T_9 N_{100}+P_{50}+K_{50}	9.93	10.00	253.21	264.00
SEm±	0.53	0.47	8.1	7.5
CD (P=0.05)	1.54	1.37	23.6	21.9

Soil characteristic

The soil analysis (Table 4) indicates that soil pH, EC and organic carbon were not affected significantly with various treatments applied in preceding mentha crop.

Table 4: Effect of various treatments on soil characteristics after harvest of maize

Treatments	I year			II year		
	pH	EC (dSm^{-1})	Org. C ($g\ kg^{-1}$)	pH	EC (dSm^{-1})	Org. C ($g\ kg^{-1}$)
T_1control	7.2	0.12	4.0	7.2	0.12	4.1
T_2 25t FYM ha^{-1}	7.1	0.11	4.4	7.2	0.12	4.5
$T_3$12.5t ha^{-1}+*Trichoderma*	7.1	0.11	4.3	7.1	0.11	4.4
T_4 25 t ha^{-1}+*Trichoderma*	7.0	0.10	4.3	7.1	0.11	4.4
T_5 N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1}	7.0	0.11	4.0	7.1	0.12	4.0
T_6 N_{50} + P_{25}+ K_{25} +*Trichoderma*	7.1	0.12	4.1	7.2	0.13	4.1
T_7 N_{50}+ P_{25}+ K_{25} + 12.5 t FYM +*Trichoderma*	7.1	0.13	4.2	7.1	0.13	4.3
T_8 N_{100}+ P_{50}+ K_{50} + *Trichoderma*	7.2	0.13	4.1	7.2	0.14	4.2
T_9 N_{100}+P_{50}+K_{50}	7.2	0.13	4.1	7.2	0.14	4.2
SEm±	0.07	0.011	0.14	0.07	0.011	0.14
CD (P=0.05)	NS	NS	NS	NS	NS	NS

Available Nutrients in Soil

Table-5 indicate the effect of different nutrient management practices on status of available nutrients in soil after harvest of maize

Table 5: Effect of different nutrient management practices on status of available nutrients in soil after harvest of maize (mean of two years)

Treatments	Nitrogen ($kg\ ha^{-1}$)	Phosphorus ($kg\ ha^{-1}$)	Potassium ($kg\ ha^{-1}$)	Iron ($mg\ kg^{-1}$)	Zinc ($kg\ ha^{-1}$)
T_1control	165.0	8.5	185.0	4.75	0.52
T_2 25t FYM ha^{-1}	180.5	8.8	196.0	4.90	0.58
$T_3$12.5t ha^{-1}+*Trichoderma*	178.0	8.8	190.0	4.80	0.56
T_4 25 t ha^{-1}+*Trichoderma*	180.0	9.0	196.5	4.81	0.60
T_5 N_{50} + P_{25} + K_{25} + 12.5 t FYM ha^{-1}	180.6	8.7	192.0	4.80	0.56
T_6 N_{50} + P_{25}+ K_{25} +*Trichoderma*	170.5	8.6	188.0	4.80	0.55
T_7 N_{50}+ P_{25}+ K_{25} + 12.5 t FYM +*Trichoderma*	178.0	8.8	192.0	4.75	0.52
T_8 N_{100}+ P_{50}+ K_{50} + *Trichoderma*	180.5	9.0	197.0	4.75	0.54
T_9 N_{100}+P_{50}+K_{50}	180.0	9.0	197.0	4.75	0.54
SEm±	5.6	0.18	4.22	0.07	0.025
CD (P=0.05)	NS	NS	NS	NS	NS

DISCUSSION

Yield attributing characters

The result in Table-1 showed that the addition of 12.5 t FYM along with N levels (50 and 100 kg ha^{-1}) in preceding mentha crop enhanced the height of maize plants over levels of NPK alone treatment in both the years. Similar results were reported by Sharma [10] and Niranjan and Arya [7]. This increase in plant height may be attributed to the mineralization of FYM or through solubilization of the nutrients from the native source during the process of decomposition. Similar results were also reported by Gaur [3]). The maximum values of these yield attributes of maize were recorded in N_{50} + P_{25} +K_{25} +12.5 t FYM ha^{-1} + *Trichoderma* treatment in both crop seasons.

Grain and stover yield

Table 2 reveals that the grain and stover yield of maize increased significantly with FYM levels over control in both crop seasons. Inoculation of *T. viride* with NPK fertilizers increased the grain and stover yield over NPK levels alone in both crop seasons. But the increases in yield were statistically non-significant. The 50 % NPK + 12.5 t FYM ha^{-1} + *T .viride* treatment applied in preceding mentha crop out yielded all the treatments in both crop seasons. The highest yield of maize under this treatment may be due to beneficial effect of FYM on soil properties and fertility status of soils. Our results revealed that FYM and crop residue incorporation significantly increased yield and yield components of maize as compared with the residues removed treatment. Similar results were obtained by Kumar & Puri [6] who reported that the application of 90 kg N ha^{-1} and 15 tons FYM ha^{-1} resulted in higher grain and straw yields of maize.

Protein Content and Protein Yield

Protein content is directly related to the N content. A further study reveals that both the levels of NPK fertilizers increased the protein yields of maize significantly over control treatment in both the years of study. Inoculation of *T. viride* with FYM levels improved the protein production but this improvement was non-significant. Application of 12.5 t FYM ha^{-1} with NPK fertilizers markedly improved the protein yield of maize crop over control in both crop seasons. This increase in protein yield may be attributed to greater production of crop and improvement in protein percentage. Application of FYM (25 t ha^{-1}) in preceding mentha crop also improved the yield of protein in maize in both crop seasons. The magnitude of increase in protein yield was higher in treatment having 50 % NPK + 12.5 t FYM ha^{-1} + *Trichoderma* as compared to other treatments. Higher ear length and weight, grain ear^{-1}, grain weight, grain and biological yields were recorded for the plots applied with FYM followed by the plots in which residues were incorporated. The plots in which no residues were incorporated performed poorly and resulted in least values of these parameters. It is concluded that application of farmyard manure at the rate of 10 tons ha^{-1} in legume cereal cropping system resulted in higher yield and yield component of maize. [1].

Soil characteristic

The soil analysis (Table 4) indicates that soil pH, EC and organic carbon were not affected significantly with various treatments applied in preceding mentha crop. Organic carbon was, however, higher in soil receiving FYM alone or in combination with NPK fertilizer and Trichoderma. Similar findings were also reported that reduction of pH and EC was not up to the level of significance under all the treatment during both the years (2014 - 2015). Among the treatment (T1 – T12) the pH values ranged from 7.70 to 7.77 during first year (2014) and during second (2015) year pH value ranged from 7.66-7.76. The major decline in pH and EC was due to the addition of FYM in various treatments. The highest value (0.35) of organic carbon was recorded in T12 (75% NPK+FYM @ 6t ha^{-1}+ ZnSO4 @ 25 kg ha^{-1} as soil application FeSO4 @ 10 kg ha^{-1} as soil application) and lowest value (0.29) of organic carbon was recorded in (T1) control during first year (2014) and similarly during second year (2015), the highest value (0.36) of organic carbon was recorded in T12 (75% NPK+FYM @ 6t ha^{-1} + ZnSO4 @ 25kg ha^{-1} as soil application FeSO4 @ 10 kg ha^{-1} as soil application)) [5] .

Available Nutrients in Soil

This may be ascribed to greater utilization of available nitrogen by maize during growth period . FYM addition along with NPK in preceding crop significantly enhanced the available N, P, K, Zn & Fe status in soil. Application of *Trichoderma* with FYM improved the status of available nitrogen, phosphoras, potassium, zinc and iron in soil. Application of FYM increased supply of available N, P, K, Zn and Fe respectively with addition of organic manures in soil, which may be ascribed to the solubilization effect of organic acids liberated during the decomposition of organic matter and organic colloids to the soil, [12].

CONCLUSION

Results of the study clearly indicate that use of FYM and *T. viride* with NPK in preceeding mentha crop increase yield attributing characters in maize resulting in higher yield with increased protein content. This combination of organic and inorganic fertilizers with bio agent also improves the soil property. This treatment may have long positive effect up to the next crop as the slow release of nutrients in organic fertilizers. Addition of *T. viride* may produce healthy seedlings as it protects from pathogens and have been reported positive growth effect on crop for long time as it is soil inhabitant fungus.

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