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Influence of validation of fertilizer prescription equations of *kharif* grain maize on micronutrient status of entisols, inceptisols and vertisols

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Abstract
The experiment was conducted on Inceptisol (Pather series, *Vertic Haplustepts*) during the year 2009-10 on experimental farm of the Soil Test Crop Response Correlation Project, M.P.K.V Rahuri for evaluation of a scientific basis for calculating the "Nutrient requirement of maize by conjoint use of FYM and chemical fertilizers based on targeted yield approach on Inceptisol". Based on the fertility gradient approach The validity of these equations were tested by conducting nine follow up trials of maize grain on three soil series of Entisol (*Viz.*Karwali, Rahuri and Akole), three soil series of Inceptisol (*Viz.* Pather, Beed and Kolyachiwadi) and three soil series of Vertisol (*Viz.*Targaon, Ambulga and Babulgaon) during *Kharif* of 2010-11 Post Graduate Farm, Dairy farm and D block, M.P.K.V. Rahuri. The results revealed that the fertilizer application as per yield target 60, 80 and 100 q ha^{-1} + 10 t ha^{-1} FYM to maize crop for validation on different soil series of Entisol (viz., Karwali, Rahuri and Akole), Inceptisol (viz., Pather, Beed and Kolyachiwadi) and Vertisol (viz., Targaon, Ambulga and Babulgaon) in respect to residual soil available DTPA micronutrients (Fe, Mn, Cu and Zn) were increased by the fertilizer application as per yield target with 10 t ha-1 FYM. Vertisols and Inceptisols soils contains more DTPA micronutrients. The soil order Inceptisols and Vertisols were higher in total uptake of iron (12.40 and 13.63 kg ha-1), zinc (1.82 and 2.14 kg ha-1), manganese (0.950 and 0.981 kg ha-1) and copper (0.760 and 0.825 kg ha-1) respectively. Soils of Vertisols and Inceptisols soil series were builtup the residual soil fertility in respect to major, secodnary and micronutrients by the addition of 10 t ha-1 FYM with yield target approach of fertilizer application.

Keywords: Influence of validation, prescription equations, micronutrient status of entisols

Introduction

Soil test and crop response (STCR) approach is based on soil contribution and yield level is used for recommending fertilizer dose. The targeted yield concept which is being widely followed since 1967 in All India Co-ordinated Research Project on STCR, which employs multiple regression equation to study the nutrient interactions. Soil test correlation approach consists of selecting a group of soils ranging in fertility from high to low in respect of a particular nutrient and testing varying dose of that particular nutrient on a crop.

STCR approach appears to be a viable technology to sustain higher crop productivity and assure better soil quality under intensive agriculture system. The IPNS based STCR equations are useful for deciding the appropriate dose of chemical fertilizers in conjunction with the organic manures. The higher returns per rupee invested on fertilizer and the high response ratio in terms of kg grain per kg nutrient obtained indicated the superiority of STCR based fertilizer recommendations for specific yield target of crops.

Maize (*Zea mays L.*) is important cereal crop of the world serving as food for man and forage for cattle. It is called as "Queen of Cereals" and "King of Fodder" due to its great importance in human and animal diet. It is a predominant source of carbohydrates and forms of staple diet of large section of the world's population. Besides as a food grain crop, maize plays a vital commercial role in Indian economy. It is used as raw material for manufacture of syrup, alcohol, starch, glucose, paper, adhesives, synthetic rubber, resins, acetic acids, lactic acids etc., the demand for which is increasing day by day. The green plant also serves as palatable fodder for cattle. Besides this, the maize produce in our country is being also utilized by poultry industries. In India the area under maize was 8.19 million hectare with production and productivity of 12.61 million tonnes and 2355 kg ha^{-1}.

In Maharashtra area under maize was 0.67 million hectare with production and productivity of 1.79 million tonnes and 2664 kg ha^{-1} (Anonymous, 2009) [1]. Maharashtra ranks fourth in terms of production of maize in the country.
Among the various methods of fertilizer recommendations the one based on yield targeting is unique in the sense that this method not only indicates soil test based fertilizer dose but also level of yield, the farmer can hope to achieve it, good agronomic practices are followed in raising the crops (Ramamurthy *et al.*, 1974) [4]. Several approaches have been used for fertilizer recommendations based on chemical soil test, so as to attain maximum yield, per unit of fertilizer use. Among the various approaches the targeted yield approach (Ramamoorthy *et al*., 1967) [5] has found popularity in India. This method not only estimates soil test based fertilizer dose but also the level of yields that the farmers can achieve with that particular dose.

Materials and Methods

The field experiment with Maize crop was conducted during 2010-2011 on soil series of Entisol (viz- Karwali Rahuri, Akole), Inceptisol (viz- Pathar, Beed, Kolyachiwadi) and Vertisol (viz-Targaon, Ambulga, babulgaon) at cental campus, Mahatma Phule Krishi Vidyapeeth, Rahuri (M.S.). The experimental farm is located under semi-arid tropics with an annual rainfall varying from 307 to 619 mm. The average annual precipitation during experiment period was 520 mm. The soil of these sites are varying in their physicsl and chemical properties. The Entisols are recently formed shallow soils, no subsurface diagnostic horizon. The soil series of experimental plot were grouped under the order Entisol comprising members of loamy, isohyperthermic and taxonomically classified as *Typic Ustorthents*. The Inceptisol soil order has a cambic horizon with its upper boundry within 100 cm of the mineral soil surface and its lower boundry at a depth of 25 cm or more below the mineral soil surface. The soils of experimental plot were grouped under the order Inceptisol and taxonomically classified as *Vertic Haplustepts*. The soils were medium deep black. The Vertisol is classified taxonomically *as Typic Haplusterts*. The soils were deep black comprising members of clayey, montmorillonitic, isohyperthermic family of *Typic Haplusterts.*

The maize grain (cv- Rajashree) was sown by dibbling in experimental plot having four replications and six treatments. The experiment was laid out in split plot design with six treatments as T_1 = Control (No fertilizer), T_2 = GRDF (120:60:40 N:P_2O_5:K_2O Kg ha^{-1}+10 t FYMha^{-1}), T_3 = As per soil test, T_4 = 60 q ha^{-1} yield target + 10 t ha^{-1} FYM, T_5 = 80 q ha^{-1} yield target + 10 t ha^{-1} FYM and T_6 = 100 q ha^{-1} yield target + 10 t ha^{-1} FYM. The Farm Yard Manure is analyzed for its nutrient contents. Maize grain was harvested and the soil samples were analysed for physicochemical properties and available macro and micro nutrients. The fertilizer prescription equations with and without FYM were developed for maize grain by using basic data NR, CS, CF and CFYM.

Fertilizer prescription equations

i) Without FYM

FN = 4.51 X T – 0.65 X SN

F P_2O_5 = 1.93 X T - 1.05 X SP

F K_2O = 2.57 X T – O.16 X SK

ii) With FYM

FN = 3.88 X T – 0.56 X SN – 3.19 X FYM(t ha^{-1})

FP_2O_5 =1.91 X T – 0.99 X SP – 1.46 X FYM(t ha^{-1})

FK_2O =2.09 X T – 0.13 X SK – 1.08 X FYM (t ha^{-1})

Where,

FN,FP_2O_5 and FK_2O is fertilizer N,P_2O_5 and K_2O in kg ha^{-1}, T is yield target (q ha^{-1}) and SN, SP and SK are soil available N,P and K in kg ha^{-1} and FYM is farm yard manure in t ha^{-1}.

Physico-chemical properties

Entisols

Recently formed shallow soils, no subsurface diagnostic horizon. The soil series of experimental plot were grouped under the order Entisol comprising members of loamy, isohyperthermic and taxonomically classified as *Typic Ustorthents*. The series includes soils of well drained and moderately permeable occurring on very gently slope of undulating topography. The soils have been interpreted as shallow and suitable for arable crops with proper management. The characteristics of soil series of Entisol soil order are as below (Table 1).

Table 1: Physico-chemical properties of soil series of Entisol, Inceptisol, Vertisol.

Sr. No.	Particulars	Entisol			Inceptisols			Vertisols		
		Karwali	Rahuri	Akole	Pather	Beed	Kolyachiwadi	Targaon	Ambulga	Babulgaon
1.	Sand	27.1	23.9	28.5	20.2	22.3	37.2	5.7	3.7	15.9
2.	Silt	32.8	34.4	31.1	30.4	25.9	20.5	32.1	31.4	26.5
3.	Clay	40.1	41.7	40.4	49.4	51.8	42.3	62.2	64.9	57.6
4.	Textural Class	Clayey	Clayey	Clayey	Clayey	Clayey	Clayey	Clayey	Clayey	Clayey
5.	Bulk density (gcc^{-1})	1.33	1.32	1.32	1.32	1.33	1.33	1.34	1.33	1.34
6.	Moisture storage capacity (mm)	59.85	73.92	53.20	194.83	191.52	127.68	309.54	307.23	377.44
7.	pH (1:2.5)	8.41	8.20	8.50	8.48	8.45	8.65	8.51	8.48	8.40
8.	EC (dSm^{-1})	0.170	0.155	0.156	0.164	0.147	0.143	0.160	0.168	0.167
9.	Organic Carbon (%)	0.67	0.57	0.54	0.63	0.66	0.52	0.51	0.60	0.64
10.	$CaCO_3$ (%)	6.00	5.00	7.25	8.75	5.75	10.25	10.00	6.00	6.50
11.	Available N ($Kgha^{-1}$)	150	150	125	150	163	175	213	163	163
12.	Available P ($Kgha^{-1}$)	9.42	9.80	9.70	8.04	11.09	8.87	11.92	12.47	9.70
13.	Available K ($Kgha^{-1}$)	224	246	269	314	347	370	358	370	179
14.	Available S ($\mu g\ g^{-1}$)	8.66	5.96	6.93	4.42	5.39	3.85	4.62	3.85	5.19
15.	Exchangeable Ca (cmol (p+) kg^{-1})	26.94	23.36	25.0	32.50	31.47	25.25	34.0	35.50	35.67
16.	Exchangeable Mg (cmol(p+) kg^{-1})	13.50	12.67	13.34	15.64	14.44	15.88	20.50	21.12	19.0
17.	DTPA Micronutrients ($\mu g\ g^{-1}$)									
I.	Fe	4.71	4.52	4.64	4.32	5.69	3.28	3.96	5.58	5.02
II.	Mn	5.45	2.52	3.33	5.87	3.68	2.57	3.11	2.98	2.75
III.	Cu	4.82	2.22	2.39	4.78	2.67	2.45	2.89	2.24	2.54

IV.	Zn	0.44	0.48	0.24	0.39	0.46	0.31	0.39	0.34	0.28
18.	Available B (μg g^{-1})	0.39	0.41	0.40	0.41	0.40	0.39	0.38	0.43	0.40
19.	Available Mo (μg g^{-1})	0.090	0.086	0.089	0.115	0.119	0.110	0.120	0.118	0.126

The texture of soil series of Karwali was clayey with low in available nitrogen (150 Kg ha^{-1}), low in available phosphorus (9.42 Kg ha^{-1}) and moderately high in potassium (224 Kg ha^{-1}). The soil was alkaline in reaction (pH 8.41). The texture of soil series of Rahuri was clayey with low in available nitrogen (150 Kg ha^{-1}), low in available phosphorus (9.80 Kg ha^{-1}) and moderately high in potassium (246 Kg ha^{-1}). The soil was moderately alkaline in reaction (pH 8.20).The texture of soil series of Akole was clayey with low in available nitrogen (125 Kg ha^{-1}), low in available phosphorus (9.70 Kg ha^{-1}) and high in potassium (269 Kg ha^{-1}). The soil was moderately alkaline in reaction (pH 8.50).

Inceptisols

A cambic horizon with its upper boundry within 100 cm of the mineral soil surface and its lower boundry at a depth of 25 cm or more below the mineral soil surface. The soils of experimental plot were grouped under the order Inceptisol and taxonomically classified as *Vertic Haplustepts*. The soils were medium deep black. The characteristics soil series of Inceptisol soil order are as below (table 1). The texture of soil series of Pather was clayey with low in available nitrogen (150 Kg ha^{-1}), low in available phosphorus (8.04 Kg ha^{-1}) and Very high in potassium (314 Kg ha^{-1}). The soil was alkaline in reaction (pH 8.48). The texture of soil series of Beed was clayey with low in available nitrogen (163 Kg ha^{-1}), low in available phosphorus (11.09 Kg ha^{-1}) and Very high in potassium (347 Kg ha^{-1}). The soil was alkaline in reaction (pH 8.45).The texture of soil series of Kolyachiwadi was clayey with low in available nitrogen (175 Kg ha^{-1}), low in available phosphorus (8.87 kg ha^{-1}) and very high in potassium (370 kg ha^{-1}). The soil was alkaline in reaction (pH 8.65).

Vertisols

A layer of 25 cm or more thick with an upper boundry within 100 cm of the mineral soil surface, that has either slickensides or wedge- shaped peds that have their long axes tilled 10 to 60 degrees from the horizontal and a weighted average of 30 per cent or more clay in the fine earth fraction either between the mineral soil surface and a depth of 18 cm or in an Ap horizon, whichever is thicker, and 30 per cent or more clay in the fine earth fraction of all horizons between a depth of 18 cm and and cracks that open and close periodically. The soil series of experimental plot were grouped under the order Vertisol and classified taxonomically *as Typic Haplusterts*. The soils were deep black comprising members of clayey, montmorillonitic, isohyperthermic family of *Typic Haplusterts.*

The series includes soils of well drained and slow permeability occurring on very gently slope (1-3 %). The soils are developed on weathering of basalt, having very dark grayish brown clay, with medium, weak angular blocky structure. The characteristics soil series of Vertisol soil order are as below (Table 1).The texture of soil series of Targaon was clayey with low in available nitrogen (213 Kg ha^{-1}), low in available phosphorus (11.92 Kg ha^{-1}) and Very high in potassium (358 Kg ha^{-1}). The soil was alkaline in reaction (pH 8.51).The texture of soil series of Ambulga was clayey with low in available nitrogen (163 Kg ha^{-1}), low in available phosphorus (12.47 Kg ha^{-1}) and Very high in potassium (370 Kg ha^{-1}). The soil was alkaline in reaction (pH 8.48). The texture of soil series of Babulgaon was clayey with low in available nitrogen (163 $Kgha^{-1}$), low in available phosphorus (9.70 Kg ha^{-1}) and Moderate in potassium (179 Kg ha^{-1}). The soil was alkaline in reaction (pH 8.40).

Results and Discussions
Residual soil micronutrients
Soil available iron
Soil order and soil series

The residual soil available iron content was numerically higher in Inceptisols (6.62 μg g^{-1}) followed by Entisols (6.43 μg g^{-1}) and Vertisols (6.28 μg g^{-1}) (Table 2). It was slightly increased than the initial iron content of soil. An increased residual soil available iron might be because of addition of iron through FYM as well as chelation action of FYM to avoid the transformation of iron in soil (Duraiswamy *et al.*, 1989) [2]. The soil series of Inceptisols recorded the higher values of soil available iron content. It was followed by Entisols and Vertisols soil series.

Table 2: Soil available iron as influenced by soil orders, series and treatments at harvest.

Order/ Series	Soil available iron (μg g^{-1})						
	T_1	T_2	T_3	T_4	T_5	T_6	Mean
Ent. S1	4.84	6.71	5.46	6.94	8.31	9.98	7.04
S2	4.18	6.61	5.28	6.73	6.85	6.96	6.10
S3	4.28	5.70	5.62	6.53	7.44	7.39	6.16
Mean	4.43	6.34	5.45	6.73	7.53	8.11	6.43
Inc. S1	5.14	7.21	6.12	8.01	8.30	8.65	7.24
S2	5.10	8.30	5.66	7.67	7.92	8.54	7.20
S3	3.27	5.66	4.69	5.66	6.46	6.75	5.41
Mean	4.50	7.06	5.49	7.11	7.56	7.98	6.62
Vert. S1	3.22	4.15	3.46	4.37	4.82	5.54	4.26
S2	4.69	7.21	6.21	7.21	7.54	7.94	6.80
S3	4.53	7.63	8.86	8.11	8.43	9.09	7.77
Mean	4.15	6.33	6.18	6.56	6.93	7.52	6.28
Grand mean	4.36	6.58	5.71	6.80	7.34	7.87	6.44

	Entisols			Inceptisols			Vertisols		
	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.
S.E.±	0.15	0.44	0.27	0.14	0.56	0.34	0.12	0.32	0.19
C.D.@ 5 %	0.53	1.66	0.76	0.49	2.13	NS	0.42	1.21	0.55
Interaction	E Vs I			E Vs V			I Vs V		

t-test	-0.368NS	0.273NS	0.577NS
Initial ava. Fe(µg g^{-1})	Entisols	Inceptisols	Vertisols
S_1	4.71	4.32	3.96
S_2	4.52	5.69	5.58
S_3	4.64	3.28	5.02

Fertilizer treatment, soil series x fertilizer treatment and interactions among soil orders

The fertilizer application recorded the significant content of residual soil available iron at harvest of grain maize in all the soil orders irrespective of soil series. The soil available iron content was considerably higher in fertilizer application as per 100 q ha^{-1} yield target + 10 t ha^{-1} FYM followed by 80 and 60 q ha^{-1} yield target + 10 t ha^{-1} FYM. The addition of FYM reduces the conversion of ferrous (Fe^{3+}) to ferric (Fe^{2+}) by their chealting action with iron. This might be enhanced residual soil available iron (Siyolkar *et al.*, 2007) [6].

Interaction effects of soil series and fertilizer application treatment for residual soil available iron were significant in Entisols and Vertisols soil order. While, it was nonsignificant in Inceptisols soil orders. This might be because of chemical properties of soil series of *viz.* organic matter, calcium carbonate content, pH, EC influenced the availability of soil available iron (Nandapure *et al.*, 2008) [3].

The interaction effects among the soil orders viz., Entisols vs. Inceptisols, Entisols vs. Vertisols and Inceptisols vs. Vertisols were nonsignificant for residual soil available iron as per t-test.

Soil Available Zinc

Soil order and soil series

Data presented in Table 3 revealed that residual soil available zinc content was numerically higher in Entisols (0.35 µg g^{-1}) and Inceptisols (0.35 µg g^{-1}) followed by Vertisols (0.28 µg g^{-1}). The initial soil available zinc content was considerably less in all the soil series of Entisols, Inceptisols and Vertisols.

The soil series of Entisols recorded the higher values of soil available zinc content. It was followed by soil series Inceptisols and Vertisols.

Fertilizer treatment, soil series x fertilizer treatment and interactions among soil order

The fertilizer application recorded the significant content of residual soil available zinc at harvest of grain maize in all the soil orders irrespective of soil series. The soil available zinc content was considerably higher in fertilizer application as per 100 q ha^{-1} yield target + 10 t ha^{-1} FYM followed by 80 and 60 q ha^{-1} yield target + 10 t ha^{-1} FYM. This mainly associated with the addition of FYM, which provides zinc, as well as humus content of FYM helds the zinc in soil to their available form (Nandapure *et al*., 2008) [3].

Interaction effects of soil series and fertilizer application treatment for residual soil available zinc were significant in Entisols, Inceptisols and Vertisols soil order. The availability of zinc due to interactive effects might be because of addition of FYM in fertilizer treatments.

Table 3: Soil available zinc as influenced by soil orders, series and treatments at harvest

Order/ Series	Soil available zinc (µg g^{-1})						
	T_1	**T_2**	**T_3**	**T_4**	**T_5**	**T_6**	**Mean**
Ent. S1	0.48	0.77	0.60	0.81	0.87	0.87	0.48
S2	0.35	0.63	0.48	0.69	0.77	0.81	0.35
S3	0.23	0.78	0.24	0.74	0.87	0.93	0.23
Mean	0.35	0.73	0.44	0.74	0.83	0.87	0.35
Inc. S1	0.38	0.56	0.48	0.66	0.72	0.77	0.38
S2	0.38	0.64	0.43	0.63	0.77	0.84	0.38
S3	0.29	0.79	0.38	0.75	0.90	0.80	0.29
Mean	0.35	0.66	0.43	0.68	0.80	0.80	0.35
Vert. S1	0.29	0.46	0.35	0.38	0.47	0.49	0.29
S2	0.31	0.61	0.44	0.63	0.68	0.79	0.31
S3	0.23	0.62	0.30	0.67	0.77	0.79	0.23
Mean	0.28	0.56	0.36	0.56	0.64	0.69	0.28
Grand mean	0.32	0.65	0.41	0.66	0.75	0.78	0.32

	Entisols			Inceptisols			Vertisols		
	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.
S.E.±	0.01	0.03	0.02	0.00	0.03	0.02	0.01	0.03	0.02
C.D.@ 5 %	0.04	0.11	0.05	0.02	0.12	0.05	0.03	0.11	0.05

Interaction	E Vs I	E Vs V	I Vs V
t-test	0.634NS	2.243*	1.701NS
Initial ava. Fe(µg g^{-1})	Entisols	Inceptisols	Vertisols
S_1	0.44	0.39	0.39
S_2	0.48	0.46	0.34
S_3	0.24	0.31	0.28

The interaction effects among the soil orders viz., Entisols vs. Inceptisols and Inceptisols vs. Vertisols were significant. While, it was nonsignificant in Entisols vs. Vertisols for zinc as per t- test.

Soil available Manganese

Soil order and soil series

The residual soil available manganese content was numerically higher in Inceptisols (4.53 µg g^{-1}) followed by Entisols (4.17 µg g^{-1}) and Vertisols (3.46 µg g^{-1}) (Table 4).The soil series of Inceptisols recorded the higher values of soil available manganese content which was followed by soil series of Entisols and Vertisols. The difference in residual manganese might be ascertained with the initial status of each soil series and their inherent soil properties.

Fertilizer treatment, soil series x fertilizer treatment and interactions among soil order

The fertilizer application recorded the significant content of residual soil available manganese at harvest of grain maize in all the soil orders irrespective of soil series. The soil available manganese content was considerably higher in fertilizer application as per 100 q ha^{-1} yield target + 10 t ha^{-1} FYM followed by 80 and 60 q ha^{-1} yield target + 10 t ha^{-1}.The differences in residual soil available manganese mainly due to addition of organics along with chemical fertilizers.

Table 4: Soil available manganese as influenced by soil orders, series and treatments at harvest.

Order/ Series	**Soil available Manganese (µg g^{-1})**								
	T_1	**T_2**		**T_3**	**T_4**	**T_5**		**T_6**	**Mean**
Ent. S1	4.55	5.45		5.04	5.64	7.16		7.19	5.84
S2	1.98	3.24		2.46	3.38	3.49		3.56	3.02
S3	2.49	3.69		3.21	3.87	4.24		4.50	3.67
Mean	3.01	4.13		3.57	4.30	4.96		5.08	4.17
Inc. S1	5.49	6.66		6.20	6.94	7.32		7.65	6.71
S2	2.18	4.15		2.74	3.41	3.94		3.92	3.39
S3	1.98	3.62		3.27	3.82	4.29		4.00	3.50
Mean	3.22	4.81		4.07	4.72	5.18		5.19	4.53
Vert. S1	2.96	4.34		3.31	4.16	4.72		5.30	4.13
S2	1.89	3.47		2.47	2.80	3.27		3.86	2.96
S3	2.25	3.68		3.35	2.83	3.88		3.68	3.28
Mean	2.37	3.83		3.04	3.26	3.95		4.28	3.46
Grand mean	2.86	4.25		3.56	4.09	4.69		4.85	4.05
	Entisol			Inceptisol			Vertisol		
	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.
S.E.±	0.13	0.44	0.27	0.07	0.48	0.29	0.05	0.30	0.18
C.D.@ 5 %	0.46	1.67	NS	0.26	1.83	NS	0.18	1.13	0.51
Interaction	E Vs I			E Vs V			I Vs V		
t-test	-0.66NS			1.782NS			2.334*		
Initial ava. Mn (µg g^{-1})	Entisols			Inceptisols			Vertisols		
S_1	5.45			5.87			3.11		
S_2	2.52			3.68			2.98		
S_3	3.33			2.57			2.75		

Interaction effects of soil series and fertilizer application treatment for residual soil available manganese were nonsignificant in Entisols and Inceptisols soil orders while, it was significant in Vertisols soil order. Fertilizer treatment consist of FYM addition provides the micronutrient and kept them in available forms by chelating actions. Hence, the interaction effects were found significant. However, initial soil available manganese content of soil also contributed role in residual soil available manganese content of soil.

The interaction effects among the soil orders viz., Entisols vs. Inceptisols and Entisols vs. Vertisols for manganese was found nonsignificant. However, it was significant in Inceptisols vs. Vertisols. This might be because of clay content, organic matter content of soil and addition of manganese through FYM application.

Soil available copper

Soil order and soil series

The residual soil available copper content was numerically higher in Inceptisols followed by Entisols (3.85 µg g^{-1}) and (3.82 µg g^{-1}) Vertisols (3.29 µg g^{-1}) (Table 5). The soil series of Inceptisols recorded the higher values of soil available copper content which was followed by soil series Entisols and Vertisols.

Table 5: Soil available copper as influenced by soil orders, series and treatments at harvest.

Order/ Series	**Soil available copper (µg g^{-1})**								
	T_1	**T_2**		**T_3**	**T_4**	**T_5**		**T_6**	**Mean**
Ent. S1	4.63	5.51		5.03	5.43	5.71		5.26	5.26
S2	1.78	3.34		2.71	3.58	3.66		3.87	3.16
S3	2.11	2.83		2.35	3.62	3.83		3.51	3.04
Mean	2.84	3.89		3.36	4.21	4.40		4.21	3.82
Inc. S1	4.63	5.04		4.72	5.24	5.67		6.29	5.27
S2	2.26	3.34		3.22	3.29	3.88		3.91	3.32
S3	2.32	2.71		3.13	2.91	3.26		3.48	2.97
Mean	3.07	3.70		3.69	3.81	4.27		4.56	3.85
Vert. S1	3.29	3.66		3.63	3.91	3.93		3.98	3.73
S2	1.82	2.85		2.58	2.91	2.95		3.36	2.74
S3	2.13	3.74		2.84	3.12	4.27		4.21	3.38
Mean	2.41	3.42		3.02	3.31	3.72		3.85	3.29
Grand mean	2.77	3.67		3.36	3.78	4.13		4.21	3.65
	Entisols			Inceptisols			Vertisols		
	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.	Series	Treat.	Series x Treat.

S.E.±	0.10	0.32	0.20	0.04	0.36	0.22	0.06	0.22	0.14
C.D.@ 5 %	0.36	1.23	0.56	0.15	1.38	NS	0.22	0.85	0.39
Interaction	E Vs I			E Vs V			I Vs V		
t-test	-0.66NS			1.782NS			2.334*		
Initial ava. Cu (μg g^{-1})	Entisols			Inceptisols			Vertisols		
S_1	4.82			4.78			2.89		
S_2	2.22			2.67			2.24		
S_3	2.39			2.45			2.54		

Fertilizer treatment, Soil series x Fertilizer treatment and interactions among soil order

The fertilizer application recorded the significant content of residual soil available copper at harvest of grain maize in all the soil orders irrespective of soil series. The soil available copper content was considerably higher in fertilizer application as per 100 q ha^{-1} yield target + 10 t ha^{-1} FYM followed by 80 and 60 q ha^{-1} yield target + 10 t ha^{-1} FYM. This was mainly because of addition of FYM.

Interaction effects of soil series and fertilizer application treatment for residual soil available copper were significant in Entisols and Vertisols soil order, while it was non significant in Inceptisols soil order. The interaction effects among the soil order viz., Entisols vs. Inceptisols, Entisols vs. Vertisols and Inceptisols vs. Vertisols were nonsignificant for copper as per t- test.

Fertilizer application to Validation trials of maize grain on different soil orders

For obtaining yield targets of 60, 80 and 100 q ha^{-1}, the fertilizer is calculated by using fertilizer prescription equation and the required amount of N, P_2O5 and K_2O is applied through the chemical fertilizers. The amount of fertilizers (Urea, SSP and MOP etc.) applied is varied with the yield targets and treatments. The fertilizer application to *Kharif* grain maize crop applied were calculated as per treatments on nutrient basis as kg ha^{-1} quantity of fertilizers of respective nutrients per plot are presented in following tables 6, 7 and 8.

Table 6: Fertilizer application to follow up trials of grain maize grown on soil series of Entisols for validation

S. No	Nutrient/Treatment	FYM (tha^{-1})	FYM (kg plot^{-1})	Nutrients (kgha^{-1})			Fertilizers (kg plot^{-1})		
				N	P_2O_5	K_2O	Urea	SSP	MOP
	Karawali								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	40	0.95	1.37	0.20
4	60 q ha^{-1}+ 10t ha^{-1} FYM	10	29.25	117	90	85	0.74	1.65	0.42
5	80 q ha^{-1}+ 10t ha^{1} FYM	10	29.25	195	128	127	1.23	2.34	0.62
6	100 q ha^{-1} +10t ha^{-1} FYM	10	29.25	272	166	169	1.72	3.03	0.82
	Rahuri								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	40	0.95	1.37	0.20
4	60 q ha^{-1}+10t ha^{-1}FYM	10	29.25	117	90	83	0.74	1.64	0.40
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	195	128	124	1.23	2.34	0.60
6	100 q ha^{-1}+10t ha^{-1} FYM	10	29.25	272	166	166	1.72	3.03	0.81
	Akole								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	20	0.95	1.37	0.10
4	60 q ha^{-1}+10t ha^{-1}FYM	10	29.25	131	90	80	0.74	1.64	0.40
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	209	128	121	1.23	2.34	0.60
6	100 q ha^{-1}+10t ha^{-1} FYM	10	29.25	286	167	185	1.72	3.03	0.81

Table 7: Fertilizer application to follow up trials of grain maize grown on soil series of Inceptisols for validation

S. No	Nutrient/Treatment	FYM (tha^{-1})	FYM (kg plot^{-1})	Nutrients (kgha^{-1})			Fertilizers (kg plot^{-1})		
				N	P_2O_5	K_2O	Urea	SSP	MOP
	Pather								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	20	0.95	1.37	0.10
4	60 q ha^{-1}+10t ha^{-1} FYM	10	29.25	117	92	95	0.74	1.67	0.46
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	195	130	116	1.23	2.37	0.56
6	100 q ha^{-1} +10t ha^{-1} FYM	10	29.25	272	168	157	1.72	3.07	0.76
	Beed								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	20	0.95	1.37	0.10
4	60 q ha^{-1}+10t ha^{-1}FYM	10	29.25	110	89	69	0.70	1.62	0.34
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	188	127	111	1.19	2.32	0.54
6	100 q ha^{-1}+ 10t ha^{-1} FYM	10	29.25	265	165	153	1.68	3.01	0.74

	Kolyachiwadi								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	40	0.95	1.37	0.20
4	60 q ha^{-1}+10t ha^{-1}FYM	10	29.25	103	91	88	0.65	1.66	0.43
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	181	129	108	1.14	2.36	0.53
6	100 q ha^{-1}+10t ha^{-1} FYM	10	29.25	258	167	150	1.63	3.05	0.73

Table 8: Fertilizer application to follow up trials of grain maize grown on soil series of Vertisols for validation.

S. No	Nutrient/Treatment	FYM (tha^{-1})	FYM (kg $plot^{-1}$)	Nutrients ($kgha^{-1}$)			Fertilizers (kg $plot^{-1}$)		
				N	P_2O_5	K_2O	Urea	SSP	MOP
	Targaon								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	30	0.95	1.37	0.15
4	60 q ha^{-1}+10t ha^{-1} FYM	10	29.25	131	90	80	0.52	1.60	0.33
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	209	128	121	1.01	2.30	0.53
6	100 q ha^{-1} +10t ha^{-1} FYM	10	29.25	286	167	185	1.50	3.00	0.74
	Ambulga								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	20	0.95	1.37	0.10
4	60 q ha^{-1}+10t ha^{-1}FYM	10	29.25	110	87	67	0.70	1.59	0.32
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	188	128	133	1.19	0.14	0.65
6	100 q ha^{-1}+10t ha^{-1} FYM	10	29.25	265	167	175	1.68	3.04	0.85
	Babulgaon								
1	Control	0	0	0	0	0	0.00	0.00	0.00
2	GRDF	10	29.25	120	60	40	0.76	1.09	0.20
3	As per soil test	0	0	150	75	40	0.95	1.37	0.20
4	60 q ha^{-1}+10t ha^{-1}FYM	10	29.25	110	90	91	0.70	1.64	0.44
5	80 q ha^{-1}+10t ha^{1} FYM	10	29.25	188	128	133	1.19	2.34	0.65
6	100 q ha^{-1}+10t ha^{-1} FYM	10	29.25	265	167	175	1.68	3.04	0.85

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