



1 **Lime and zinc application influence soil zinc availability, dry**
2 **matter yield and zinc uptake by maize grown on Alfisols**

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16 ABSTRACT

17 Zinc (Zn) deficiency is widespread in all types of soils of world including acid soils affecting
18 crop production and nutritional quality of edible plant parts. There is, however, limited
19 information available regarding effects of lime and farmyard manure (FYM) addition on soil
20 properties, phyto-available Zn by different extractants, dry matter yield, Zn concentration and
21 uptake by maize (*Zea mays* L.). Green house pot experiments were carried out in two acid
22 soils to study the effect of five levels of lime (0, 1/10 lime requirement (LR), 1/3 LR, 2/3
23 LR and LR), three levels of Zn concentration (0, 2.5 and 5.0 mg Zn kg⁻¹ soil) and two levels
24 of FYM (0 and 10 t ha⁻¹) addition on soil pH, EC and OC content, phyto-available Zn in soil
25 and dry matter yield, Zn concentration and uptake by maize plant grown up to 60 days.
26 Application of lime and FYM improved soil pH. Increased level of lime application reduced
27 Zn extracted by DTPA, Mehlich 1, Mehlich 3, 0.1 N HCl and ABDTPA extractants.
28 However, application of FYM along with lime improved Zn extraction. The amount of Zn
29 extracted by different extractants followed the order DTPA-Zn < ABDTPA-Zn < Mehlich-1
30 Zn < 0.1 M HCl. Lime rate of 1/3rd LR was found to be optimum as dry matter yield of maize
31 increased significantly with lime application up to 1/3rd LR in soils of both the series and
decreased subsequently. Addition of FYM with and without lime increased dry matter yield.



32 Application of Zn up to 5.0 mg kg⁻¹ to soil increased dry matter yield with and without FYM
33 application in soils of Hariharapur series. Addition of higher doses of lime significantly
34 reduced Zn concentration in maize crop grown in soils of both the series. Mean Zn uptake
35 values were at par for no lime, 1/10th LR and 1/3rd LR with and without FYM application and
36 it was significantly higher than Zn uptake by 2/3rd LR and LR treatments. However, FYM
37 application improved Zn uptake by maize crop. Zn extracted by different extractants like
38 DTPA, ABDTPA, Mehlich 1, Mehlich 3 and 0.1 M HCl was positively and significantly
39 correlated amongst themselves and with dry matter yield, Zn concentration and Zn uptake by
40 maize.


41 *Keywords:* Alfisols, Lime, Farmyard manure, Zinc, Maize

42 **1. Introduction**

43 Globally, zinc (Zn) deficiency is the most widespread micronutrient deficiency problem
44 resulting in reduced crop production and nutritional quality of edible plant parts (Cakmak,
45 2002). It is more prevalent in cereal growing areas and nearly 50% of world's cereal
46 growing areas are having soils with low plant-available Zn. It has also been reported in
47 almost all countries (Alloway, 2008) including India in different soil types (Takkar, 1996;
48 Shukla et al., 2014). It is commonly prevalent in high pH calcareous soils (Katyal and Vlek,
49 1985), and leached, heavily weathered and sandy acid soils with low organic matter content
50 (Rautaray et al., 2003; Behera et al., 2011).

51 Soil acidity is a serious problem affecting crop production across the world including
52 India which is having 34.5% of arable land with acid soils (Maji et al., 2012). Ameliorating
53 acid soils with suitable amendments and proper nutrient especially Zn management in acid
54 soils are areas of concern for obtaining higher crop yield. Amelioration of acidic soils is
55 beneficial to plant growth because it improves soil pH and replenishes nutrients (Moon et al.,




2014). Application of liming material is an effective method for amelioration of acid soils (Ponnette et al., 1991; Quoggio et al., 1995). Lime is normally oxides, carbonates and hydroxides of calcium or magnesium. There are about four types of lime viz., quicklime (CaO), slaked lime (Ca(OH)₂), limestone (CaCO₃) and dolomite. Application CaCO₃ to acid soils reduced soil acidity, improved basic cations status and significantly increased the yields of crops grown on Ultisol (Cifu et al., 2004).  However, adoption of standard recommendation of lime requirement (LR) for different groups of acid soils is difficult for farmers, which is uneconomical and unsustainable. Therefore, lower doses of LR like 1/10th, 1/3rd and 2/3rd of LR are applied by the farmers. There is dearth of information regarding the application of different doses of lime on Zn availability in acid soils.

Soil pH and organic matter content are the most important soil factors affecting phyto-availability of Zn in soil (Suman, 1986; Lindsay, 1992). Increased soil pH due to addition of lime can influence availability of Zn in soil by altering its equilibrium (Verma and Minhas, 1987). Higher level of soil pH results in reduced extractable Zn content due to increased adsorptive capacity, formation of hydrolyzed forms of zinc, chemisorption on calcium carbonate and co-precipitation in iron oxides (Cox and Kamprath, 1972). Available organic materials such as farmyard manure (FYM) are generally used by the farmers along with chemical fertilizers because it improves soil physical, chemical and biological properties (Nambiar, 1994). Addition of organic matter to soil results in enhanced microbiological activity which adds complexing agents as well as influences the redox status of soil. According to Moody et al. (1997) higher levels of organic matters enhance Zn availability by increasing exchangeable and organic fractions of Zn and reducing oxide fractions of Zn. The effect of addition of organic matter on Zn availability in soils has also been reported by different workers (Murthy, 1982; Ghanem and Mikkelsen, 1987). But the information






80 regarding influence of addition of lime with and without FYM to acid soils on Zn availability
81 in soil and Zn concentration and Zn uptake by crops is limited.


82 Appropriate soil tests for plant available metal are not yet available for all types of
83 agricultural soils around the world. However, extractants like diethylene triamine penta
84 acetic acid (DTPA), ethylene diamine tetra acetic acid (EDTA), hydrochloric acid,
85 ammonium bicarbonate-DTPA (ABDTPA) , Mehlich 1 and Mehlich 3 are used for
86 extraction of plant available Zn from soils (Alloway, 2008). But DTPA extractant is the most
87 widely used. The DTPA soil test was originally developed to categorize near-neutral and
88 calcareous soils with insufficient plant available Zn to support maximum yield of crops
89 (Lindsay and Norvell, 1978). But the same has been used for acid soils also for extraction of
90 plant available Zn. According to O'Connor (1988), whenever one strays from the original
91 design of the test, one should be aware of the possible consequences and pass that awareness
92 on to others. Based on correlation among the extracted Zn by different extractants and with
93 soil properties, Behera et al. (2011) reported the usefulness of DTPA, Mehlich 1, Mehlich 3,
94 0.1 N HCl and ABDTPA extractant for extraction of plant available Zn in acid soils of India.
95 But there is scanty information available regarding the relationship of extracted Zn by
96 different extractants with Zn concentration and uptake by crop plants. efore, the present
97 study was carried out to evaluate the influence of lime and FYM addition on soil pH, EC and
98 OC content, extracted Zn as extracted by different extractants and dry matter yield, Zn
99 concentration and uptake by maize (*Zea mays* L.) and to analyze the relationship amongst
100 them.

101 **2. Materials and methods**

102 *2.1 Soil characteristics and methods of soil analysis*



103 The bulk surface (0-15 cm depth) soils collected from Hariharpur series (Oxic Haplustalfs 
104 (Bhubaneswar, India) and Debatoli series (Udic Rhodostalfs) (Ranchi, India) were used in the
105 study. These soils were representative typical soils found in India. Selected characteristics of
106 these soils are given in Table 1. The collected soil samples were air dried and stone and
107 debris were removed and then ground to pass a 2 mm sieve. The samples were then stored for
108 subsequent analysis. Soil properties like pH and EC were determined done on 1: 2.5 soil
109 water ratio (w/v) suspension using pH meter and EC meter following half an hour
110 equilibrium (Jackson, 1973). Soil organic carbon (OC) content was estimated by chromic
111 acid digestion-back titration method (Walkley and Black, 1934). The clay, silt and sand per
112 cent of soils were determined by hydrometer method (Bouyoucos, 1962). Calcium carbonate
113 (CaCO₃) content was determined by rapid titration method (Puri, 1930) and cation exchange
114 capacity (CEC) by neutral normal ammonium acetate method (Richards, 1954). Lime
115 requirement (LR) of the soil was estimated by extractant buffer method (Shoemaker et al.,
116 1961). The plant available Zn in soils was extracted by DTPA method (Lindsay and Norvell,
117 1978). After drying of FYM at 70 °C for 24 h followed by grinding to pass through 20 mesh
118 sieve, one gram of ground FYM was dry-ashed at 450 °C for 2h. Ashed samples were
119 extracted using 0.5 N HCl. Zn concentration was determined in filtered extracts. The OC, N,
120 P and K concentrations in FYM were estimated by appropriate meth  Jackson, 1973). The
121 OC, N, P, K and Zn content in FYM (on dry weight basis) were 0.12% 0.48%, 0.10%, 0.55% 
122 and 12 mg kg⁻¹ respectively.

123 Replicated soil samples were collected after harvesting of maize p s. Collected soil
124 samples were processed and analyzed for pH, EC, OC content and DTPA-Zn concentration
125 by the methodologies described above. The plant available Zn in soils was also extracted by
126 Mehlich 1 (Perkins, 1970), 0.1 M HCl (Sorensen et al., 1971) and ABDTPA (Soltanpour
127 and Schwab, 1977) extractants by following the respective prescribed methods. Estimation of



128 Zn concentration was done on the clear extract by atomic absorption spectrophotometer
129 (AAS).

130 2.2 Green house study

131 Pot experiments were carried out in two Hariharapur and Debatoli series soils. The
132 experiments were carried out in plastic pots having 4 kg of soil with five levels of LR (0, 1/10
133 LR, 1/3 LR, 2/3 LR and LR), three levels of Zn concentration (0, 2.5 and 5.0 mg Zn kg⁻¹ soil)
134 and two levels of fresh FYM (35% moisture) (0 and 10 t ha⁻¹). All the pots received basal
135 treatments of N-P₂O₅-K₂O @ 150-60-40 kg ha⁻¹. Fertilizer N, P and K were applied through
136 analytical grade urea, calcium dihydrogen orthophosphate and muriate of potash,
137 respectively. Lime and Zn were added to soil through laboratory grade CaCO₃ and ZnSO₄
138 respectively. All nutrients were mixed in soil thoroughly before sowing of seeds. The soil in
139 each plot was then irrigated to field capacity with deionized water and kept for incubation for
140 one week. Each treatment combination was replicated thrice in a factorial completely
141 randomized design. Four seeds of cv. KH 101 of maize were sown in each pot. Two
142 seedlings of maize per each pot were maintained after emergence. Pots were irrigated with
143 water daily as per requirement of water on weight basis to maintain the field capacity. Above-
144 ground biomass of plants from each pot was harvested at the end of 60 days of growth.

145 2.3 Plant analysis

146 Harvested above-ground biomass of each pot was washed in deionized water, and then dried
147 in oven at 70 °C for 48 h. After drying, dry matter yield (DMY) of each pot was recorded.
148 Dried plant material was then ground in a stainless steel Wiley mill, and digested in a di-
149 acid mixture of HNO₃ and HClO₄ (Jackson, 1973). Zn concentration was then determined in
150 aqueous extracts of the digested plant material by atomic absorption spectrophotometer
151 (AAS). Zn uptake was calculated as DMY multiplied by the Zn concentration.




152 *2.4 Statistical analysis*

153 The data regarding soil properties, DMY, Zn concentration, Zn uptake and extracted Zn by
154 different extractants subjected to analysis of variance method (Gomez and Gomez 1984).
155 Least square difference (LSD) at $P \leq .01$ was used to compare among the treatment means.
156 Pearson's correlation coefficient values were estimated to establish relationship among soil
157 properties, DMY, Zn concentration, Zn uptake and extracted Zn by different extractants.

158 **3. Results**

159 *3.1 Soil properties*

160 Application of lime at different rates significantly increased pH in soils of both
161 Hariharapur and Debatoli series (Table 2, Fig. 1 a). With addition of graded doses of limes
162 viz. from no lime, 1/10th LR, 1/3rd LR, 2/3rd LR and LR, soil pH increased from 4.58 to 7.16
163 (without FYM addition) and from 4.89 to 7.23 (with FYM addition) in Hariharapur series and
164 from 5.83 to 6.95 (without FYM addition) and from 6.04 to 7.02 (with FYM addition) in
165 Debatoli series. Application of FYM without lime increased soil pH in both the soils (Table
166 2). Combined application of lime and FYM also enhanced soil pH significantly. Addition of
167 Zn did not have any effect on soil pH. Application of lime, FYM and Zn did not influence
168 soil EC levels in soils of both the series (Table 2, Fig. 1 b). However application of FYM
169 increased soil OC content in soils of both series (Table 2, Fig. 1c). Addition of lime and Zn
170 did not influence soil OC 


171 *3.2 Extractable zinc in post-harvest soil*

172 Data regarding amount Zn extracted by DTPA, Mehlich 1, 0.1 M HCl and ABDTPA
173 extractants in post harvest soil are given in Table 3. The amount of extracted Zn by DTPA,
174 Mehlich 1, and ABDTPA extractants decreased with increased level of lime application in
175 soils of both the series (Fig. 2 a, b, d). But addition of FYM (@ 10 t ha⁻¹) in combination of



176 different levels of lime led to marked enhancement of extracted Zn by different extractants in
177 both the soils compared to only application of different lime levels (Table 3). Application Zn
178 at different levels viz. 2.5 and 5.0 mg kg⁻¹ with and without FYM increased the concentration
179 of extracted Zn by the different extractants. The amount of Zn extracted by different
180 extractants varied widely and it followed the order DTPA-Zn < ABDTPA-Zn < Mehlich-1 Zn
181 < 0.1 M HCl.

182 3.3 Dry matter yield

183 DMY of maize increased significantly with lime application up to 1/3rd LR (Table 4, Fig.
184 3 a) in soils of both the series. This indicated that lime application @ 1/3rd of LR was
185 optimum for these soils.  Application of higher doses of lime (2/3rd LR and LR) did not result
186 in increased DMY. The mean DMY in 1/3rd LR treatment without FYM and with FYM was
187 139% and 149% of control respectively in Harihpur series soils. Similarly in Debatoli series
188 soil, the mean DMY was 84% and 120% of control without and with FYM application
189 respectively in combination with 1/3rd LR. Application of graded doses of Zn upto 5.0 mg kg⁻
190 ¹ to soil increased DMY with and without FYM application in Hariharapur series. Whereas in
191 Debatoli series, application of graded doses of Zn up to 5 mg kg⁻¹ without FYM and
192 application of Zn @ 2.5 mg kg⁻¹ with FYM enhanced DMY.

193 3.4 Zinc concentration and uptake by maize

194 Addition of higher doses of lime significantly reduced Zn concentration in maize crop
195 grown in soils of both the series (Table 4, Fig. 3 b). In contrast, application of Zn (@ 2.5 and
196 5.0 mg kg⁻¹) and FYM (@ 10 t ha⁻¹) increased Zn concentration in maize crop significantly in
197 soils of both the series (Table 4). In soils of Hariharapur series, application Zn @ 2.5 and 5
198 mg kg⁻¹ without and with FYM augmented Zn concentration in maize by 67.5 and 93.5 to 109
199 % respectively as compared to control (No Zn). Similarly, increased Zn concentrations of 22



200 to 35 and 58 to 73% were recorded with application of Zn @ 2.5 and 5 mg kg⁻¹ without and
201 with FYM respectively in comparison to no Zn control in soils of Debatoli series. Mean Zn
202 uptake values were at par for no lime, 1/10th LR and 1/3rd LR with and without FYM
203 application and it was significantly higher than Zn uptake by 2/3rd LR and LR treatments in
204 soils of both the series (Table 4, Fig. 3 c). However, Zn and FYM application improved Zn
205 uptake by maize crop in soils of both series. Addition of Zn @ 2.5 and 5 mg kg⁻¹ enhanced
206 Zn uptake by 67 to 100 and 122 to 150% respectively as compared to no Zn control in soils
207 of Hariharapur series. Whereas, the enhancements in Zn uptake were 36 to 50, 73 to 117%
208 due to application of Zn @ 2.5 and 5 mg kg⁻¹ respectively as compared to no Zn control in
209 soils of Debatoli series.

210 4. Discussion

211 Lime is a basic chemical and its application neutralizes soil acidity (H⁺ and Al³⁺ ions) and
212 makes soil more basic. In this study, application of increased rate of lime also enhanced soil
213 pH. Anikwe et al. (2016) also reported increase in soil pH due to lime addition in an Ultisol
214 of Nigeria. Application of lime along with FYM also enhanced soil pH. This is in line with
215 the findings of Saha et al. (2012). Normally, addition of organic matter lowers soil pH by
216 releasing H⁺ ions associated with organic anions or by nitrification in an open system
217 (Porter et al., 1980). But in contrary, it may cause pH increases either by mineralization of
218 organic anions to CO₂ and water (thereby removing H⁺ ions) or because of the 'alkaline'
219 nature of the organic material (Helyar, 1976). Increase in soil pH due to addition FYM in our
220 study may be due to operation of the second mechanism.


221 Application of lime reduced the concentrations of extractable Zn extracted by DTPA,
222 Mehlich 1 and ABDTPA extractants. Reduced availability of Zn in soil due to liming has also
223 been reported by Tlustos et al. (2006) and Vondrackova et al. (2013). It is because of



224 conversion of plant available fractions of Zn to plant unavailable fractions resulting in
225 effective immobilisation (Davis-Carter and Shuman, 1993). But application of FYM
226 improved the concentrations of extracted Zn. Addition of organic matter led to formation of
227 organic acids by microbial decomposition, which mobilize soil bound Zn and restrict the
228 fixation of soluble Zn by chelating it (Shukla, 1971; Sarkar and Deb, 1982; Tagwira et al.,
229 1992). It has also been reported by Saha et al. (1999) that application of organic matter to
230 cultivated acid soils was essential to counteract the adverse effect of lime application on Zn
231 availability. Application Zn with and without FYM enhanced the concentrations of extracted
232 Zn significantly. Rupa et al. (2003) also reported increased concentration of exchangeable
233 plus water soluble, inorganically, organically and oxide bound Zn in two Alfisols due to
234 addition of increased Zn rates.

235 Among the extractants used in this study, DTPA extracted lowest amount of Zn. This is
236 in agreement with the findings of Behera et al. (2011) who reported lowest amount of Zn
237 extracted by DTPA compared other extractants like Mehlich 1, Mehlich 3, 0.1 M HCl and
238 ABDTPA, by analysing four hundred soil samples collected from cultivated acid soils of
239 India. This may be ascribed to lower extracting power of DTPA in these soils owing to
240 reduced active sites of DTPA at lower pH values. Higher extractability of ABDTPA
241 compared to DTPA in these soils because of ABDTPA solution pH of 7.6 which allowed
242 DTPA to chelate and extract more Zn from soil. Mehlich 1 extractant which was originally
243 developed for prediction of plant available P in acidic coastal plain soil (pH<6.5) with low
244 cation exchange capacity (CEC<10meq/100g) and low organic matter (<5%), extracted more
245 amount of Zn compared to DTPA and ABDTPA extractants. Higher extractability of Zn by
246 0.1 M HCl has also been reported by Naik and Das (2010) as compared to DTPA and 0.05 M
247 HCl extracted Zn in low land rice soils. This is because 0.1 M HCl extracts Zn from freshly
248 adsorbed iron and manganese oxides, carbonates, or decomposing organic matter and Zn



249 bound with the octahedral-OH in layer silicates (Hodgson, 1963). Dilute mineral acids of pH
250 1-2 showed the greatest extracting power for extraction of Zn, followed by buffered solutions
251 of pH 7-9 containing chelating agents and buffers or very dilute acids of pH 4-5 (Misra et al.,
252 1989). Zhang et al. (2010) reported Zn extraction capacity of different extractants in the order
253 of EDTA > Mehlich 3 > Mehlich 1 > DTPA > NH₄OAc > CaCl₂ in polluted soils of rice in
254 south-eastern China. The amount Zn extracted in polluted soils of central Iran followed the
255 order Mehlich 3 > ABDTPA > DTPA > Mehlich 2 > CaCl₂ > HCl (Hosseiwnpur and
256 Motaghian, 2015). 

257 Significant increase in DMY was recorded with application of lime up to 1/3rd LR.
258 Increase in DMY with lime application up to 1/3rd LR may be ascribed to increase in soil pH
259 and positive influence on nutrient availability in soil (Tisdale, 2005). Increased DMY due to
260 FYM addition may be due to positive influence of on nutrient availability and uptake.
261 Increased DMY due to Zn addition in soils of Hariharapur series revealed that Zn is a limiting
262 nutrient in this soil. It was evident from low initial DTPA-Zn status (0.47 mg kg⁻¹) of this
263 soil. Grain and vegetative tissue (stover) yield of maize increased significantly with
264 successive application of Zn up to 1 kg ha⁻¹ in a Zn-deficient (DTPA-Zn 0.38 mg kg⁻¹)
265 Vertisol of India (Behera et al., 2015). Zn addition to a soil with 0.18 mg kg⁻¹ Zn enhanced
266 wheat grain yield (Cakmak et al., 2010a; Cakmak et al., 2010b). However in Debatoli series,
267 DMY response to Zn application was obtained in spite of high initial DTPA-Zn status (1.45
268 mg kg⁻¹) which needs further investigation. In contrast to our findings, Zhang et al. (2012)
269 and Wang et al. (2012) reported that zinc fertilizer application did not improve the biomass
270 and grain yields of wheat and maize in rain-fed and low Zn calcareous soils of China. This
271 may be attributed to Zn availability in soil influenced by several factors (Alloway, 2009)
272 and efficiency of the crops/genotypes to utilize available Zn in soils (Cakmak et al., 1998).



273 Addition of lime significantly reduced Zn concentration. This may be due to reduced
274 availability Zn in soil due to increased soil pH. Soil pH significantly influences Zn
275 distribution among different fractions and availability in soil (Sims, 1986; Smith, 1994) and
276 the plant uptake is primarily related with different Zn fractions (Behera et al., 2008).
277 However, FYM and Zn application improved Zn concentration in maize. Application of 5
278 and 10 mg Zn kg⁻¹ enhanced Zn concentration of navy bean shoot from 19.93 mg kg⁻¹ to
279 38.12 and 54.8 mg kg⁻¹ respectively (Gonzalez et al., 2008). Significant increase in Zn
280 concentration in ear leaves of spring maize, shoots of wheat and in maize and wheat grains
281 was also reported by Wang et al. (2012). Payne et al. (1988) also reported increased Zn
282 concentration in maize grain under highest ZnSO₄ application from a long-term experiment.

283 Soil pH was negatively and significantly correlated with Zn concentration ($r = -0.509^{**}$, r
284 $= -0.343^{**}$) and Zn uptake by maize ($r = -0.397^{**}$, $r = -0.326^{**}$) in both the soil series (Table
285 5). This revealed that increased soil pH resulted in decreased Zn concentration and Zn uptake
286 in maize and vice versa. Wang et al. (2006) also recorded increased Zn concentration in
287 *Thlaspi caerulescens* with decreased soil pH. Soil OC content was positively and
288 significantly correlated with DMY ($r = 0.221^{*}$), Zn concentration ($r = 0.232^{*}$) and Zn uptake
289 ($r = 0.294^{**}$) in Hariharpur series only. It was also positively and significantly correlated
290 with DTPA, Mehlich 1 and 0.1 M HCl extracted Zn in soils of both the series. This is in line
291 with the findings of Katyal and Sharma (1991) and Shidhu and Sharma (2010). DMY was
292 positively and significantly correlated with Zn uptake ($r = 0.605^{**}$, 0.727^{**}) in soils of both
293 the series. It was also positively and significantly correlated with Zn extracted by DTPA,
294 Mehlich 1, 0.1 M HCl and ABDTPA extractants in Hariharpur series and Zn extracted by
295 Mehlich 1, 0.1 M HCl and ABDTPA extractants in Debatoli series. Zn concentration in
296 maize was positively and significantly correlated with Zn uptake by maize and extracted Zn
297 by different extractants in soils of both the series. Positive and significant correlation



298 coefficient values were also obtained for Zn uptake vs Zn extracted by different extractants in
299 soils of both the series. Zn extracted by different extractants in soils of both series were
300 positively and significantly correlated with each other. The values of correlation coefficients
301 ranged from $r = 0.811^{**}$ to $r = 0.937^{**}$. This indicated that the trend of extraction of Zn from
302 both the soils, by different extractants used in the study is similar. It corroborates the findings
303 of Gartley et al. (2002), Mylavarapu et al. (2002), Nascimento et al. (2007) and Behera et al.
304 (2011) who have reported the suitability of extractants like DTPA, ABDTPA, Mehlich 1,
305 Mehlich 3 and 0.1 M HCl for extraction of phyto-available Zn in acids of different parts of
306 the world. Since Zn extracted by different extractants like DTPA, ABDTPA, Mehlich 1,
307 Mehlich 3 and 0.1 M HCl was positively and significantly correlated amongst themselves
308 and with DMY, Zn concentration and Zn uptake by maize, all these extractants can be used
309 for extraction of Zn from acid soils.

310 5. Conclusion

311 From the study, it is concluded that application of lime with and without FYM
312 influenced phyto-available Zn extracted by different extractants like DTPA, ABDTPA,
313 Mehlich 1, Mehlich 3 and 0.1 M HCl in two acid soils of India. Increased level of lime
314 application led to enhancement of soil pH and reduction in extractable Zn in soils of both the
315 series and Zn concentration in maize. Lime application of 1/3LR was found to be optimum
316 for amelioration in these soils. Application of FYM along with lime improved the
317 concentration of extractable Zn in soil. Soil OC content was positively and significantly
318 correlated with Zn extracted by different extractants. Since DTPA, ABDTPA, Mehlich 1,
319 Mehlich 3 and 0.1 M HCl extractable Zn in soils of both the series were positively and
320 significantly correlated with dry matter yield, Zn concentration and Zn uptake, these
321 extractants could be used for extraction of Zn in acid soils.





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488 **Table 1** Some selected characteristics of the experimental soils.

| Soil characteristics | Hariharapur series | Debatoli series |
|---|--------------------|------------------|
| Taxonomic classification | Oxic Haplustalfs | Udic Rhodustalfs |
| pH (1:2.5) | 4.50 | 5.80 |
| EC (dS m ⁻¹) | 0.14 | 0.23 |
| Organic carbon (%) | 0.31 | 0.22 |
| Clay (%) | 12.1 | 14.2 |
| Silt (%) | 15.0 | 11.6 |
| Sand (%) | 73.2 | 75.1 |
| CaCO ₃ (%) | 20.0 | 32.0 |
| CEC (cmol(p ⁺) kg ⁻¹) | 3.90 | 5.10 |
| Lime requirement (g kg ⁻¹) | 3.34 | 1.51 |
| DTAP-Zn (mg kg ⁻¹) | 0.47 | 1.45 |



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Table 2 Soil pH, EC and OC content as influence by FYM, lime and Zn application.

| Treatments | No FYM | | | | FYM (10 t ha ⁻¹) | | | | |
|--------------------------|--|----------------------------|----------------------------|------|------------------------------|----------------------------|----------------------------|------|--------------|
| | No Zn | 2.5 mg Zn kg ⁻¹ | 5.0 mg Zn kg ⁻¹ | Mean | No Zn | 2.5 mg Zn kg ⁻¹ | 5.0 mg Zn kg ⁻¹ | Mean | Overall mean |
| Hariharapur series | | | | | | | | | |
| No lime | 4.56 | 4.57 | 4.61 | 4.58 | 5.16 | 5.10 | 5.34 | 5.20 | 4.89 |
| 1/10 th LR | 4.80 | 5.01 | 4.83 | 4.88 | 5.46 | 5.42 | 5.44 | 5.44 | 5.16 |
| 1/3 rd LR | 5.69 | 6.14 | 5.57 | 5.80 | 5.93 | 6.49 | 5.97 | 6.13 | 5.97 |
| 2/3 rd LR | 6.45 | 6.53 | 6.62 | 6.53 | 6.92 | 7.08 | 6.57 | 6.86 | 6.70 |
| LR | 7.23 | 7.25 | 6.99 | 7.16 | 7.37 | 7.17 | 7.38 | 7.31 | 7.23 |
| Mean | 5.75 | 5.90 | 5.72 | - | 6.17 | 6.25 | 6.14 | - | - |
| LSD (0.01) | Lime = 0.19, Zn level = ns, FYM level = 0.25, Lime x Zn level = ns, Lime x FYM level = 0.51, Zn level x FYM level = ns | | | | | | | | |
| EC (dS m ⁻¹) | | | | | | | | | |
| No lime | 0.14 | 0.11 | 0.13 | 0.13 | 0.13 | 0.15 | 0.14 | 0.14 | 0.13 |
| 1/10 th LR | 0.14 | 0.10 | 0.10 | 0.12 | 0.15 | 0.11 | 0.12 | 0.13 | 0.12 |
| 1/3 rd LR | 0.13 | 0.13 | 0.11 | 0.12 | 0.12 | 0.10 | 0.14 | 0.12 | 0.12 |
| 2/3 rd LR | 0.12 | 0.13 | 0.11 | 0.12 | 0.12 | 0.15 | 0.10 | 0.12 | 0.12 |
| LR | 0.13 | 0.14 | 0.12 | 0.13 | 0.15 | 0.14 | 0.15 | 0.15 | 0.14 |
| Mean | 0.13 | 0.12 | 0.11 | - | 0.13 | 0.13 | 0.13 | - | 0.13 |
| LSD (0.01) | Lime = ns, Zn level = ns, FYM level = ns, Lime x Zn level = ns, Lime x FYM level = ns, Zn level x FYM level = ns | | | | | | | | |
| OC (%) | | | | | | | | | |
| No lime | 0.26 | 0.27 | 0.25 | 0.26 | 0.32 | 0.37 | 0.34 | 0.34 | 0.30 |
| 1/10 th LR | 0.27 | 0.24 | 0.27 | 0.26 | 0.33 | 0.34 | 0.39 | 0.35 | 0.31 |
| 1/3 rd LR | 0.25 | 0.24 | 0.27 | 0.25 | 0.31 | 0.36 | 0.37 | 0.35 | 0.30 |
| 2/3 rd LR | 0.27 | 0.25 | 0.23 | 0.25 | 0.30 | 0.34 | 0.32 | 0.32 | 0.29 |
| LR | 0.24 | 0.21 | 0.22 | 0.22 | 0.25 | 0.34 | 0.33 | 0.31 | 0.27 |
| Mean | 0.26 | 0.24 | 0.25 | - | 0.30 | 0.35 | 0.35 | - | - |
| LSD (0.01) | Lime = ns, Zn level = ns, FYM level = 0.03, Lime x Zn level = ns, Lime x FYM level = ns, Zn level x FYM level = ns | | | | | | | | |



| Debatoli series | | | | | | | | | | |
|-----------------------|--|------|------|------|------|------|------|------|------|--|
| | pH | | | | | | | | | |
| No lime | 5.88 | 5.85 | 5.77 | 5.83 | 6.14 | 6.17 | 6.45 | 6.25 | 6.04 | |
| 1/10 th LR | 5.93 | 5.88 | 5.94 | 5.92 | 6.28 | 6.42 | 6.56 | 6.42 | 6.17 | |
| 1/3 rd LR | 6.38 | 6.21 | 6.21 | 6.27 | 6.44 | 6.57 | 6.58 | 6.53 | 6.40 | |
| 2/3 rd LR | 6.64 | 6.67 | 6.6 | 6.64 | 6.76 | 6.75 | 6.64 | 6.72 | 6.68 | |
| LR | 6.96 | 6.99 | 6.9 | 6.95 | 7.27 | 6.87 | 7.14 | 7.09 | 7.02 | |
| Mean | 6.36 | 6.32 | 6.28 | - | 6.58 | 6.56 | 6.67 | - | - | |
| LSD (0.01) | Lime = 0.17, Zn level = ns, FYM level = 0.20, Lime x Zn level = ns, Lime x FYM level = 0.47, Zn level x FYM level = ns | | | | | | | | | |
| | EC (dS m ⁻¹) | | | | | | | | | |
| No lime | 0.23 | 0.22 | 0.27 | 0.24 | 0.21 | 0.26 | 0.23 | 0.23 | 0.24 | |
| 1/10 th LR | 0.27 | 0.27 | 0.23 | 0.25 | 0.21 | 0.23 | 0.20 | 0.21 | 0.24 | |
| 1/3 rd LR | 0.23 | 0.23 | 0.24 | 0.23 | 0.17 | 0.29 | 0.25 | 0.24 | 0.24 | |
| 2/3 rd LR | 0.23 | 0.21 | 0.21 | 0.21 | 0.23 | 0.19 | 0.24 | 0.22 | 0.22 | |
| LR | 0.24 | 0.17 | 0.29 | 0.23 | 0.19 | 0.30 | 0.26 | 0.25 | 0.24 | |
| Mean | 0.24 | 0.22 | 0.25 | - | 0.20 | 0.25 | 0.24 | - | - | |
| LSD (0.01) | Lime = ns, Zn level = ns, FYM level = 0.04, Lime x Zn level = ns, Lime x FYM level = ns, Zn level x FYM level = ns | | | | | | | | | |
| | OC (%) | | | | | | | | | |
| No lime | 0.21 | 0.28 | 0.22 | 0.24 | 0.22 | 0.29 | 0.30 | 0.27 | 0.25 | |
| 1/10 th LR | 0.22 | 0.22 | 0.21 | 0.22 | 0.28 | 0.28 | 0.28 | 0.28 | 0.25 | |
| 1/3 rd LR | 0.21 | 0.25 | 0.24 | 0.23 | 0.28 | 0.26 | 0.29 | 0.28 | 0.26 | |
| 2/3 rd LR | 0.18 | 0.22 | 0.25 | 0.21 | 0.31 | 0.25 | 0.28 | 0.28 | 0.25 | |
| LR | 0.21 | 0.25 | 0.26 | 0.24 | 0.28 | 0.30 | 0.28 | 0.28 | 0.26 | |
| Mean | 0.21 | 0.24 | 0.24 | - | 0.27 | 0.27 | 0.29 | - | - | |
| LSD (0.01) | Lime = ns, Zn level = ns, FYM level = 0.04, Lime x Zn level = ns, Lime x FYM level = ns, Zn level x FYM level = ns | | | | | | | | | |



Table 3 Effect of FYM, lime and Zn application on extractable Zn in soils.

| Treatments | No FYM | | | FYM (10 t ha ⁻¹) | | | Overall mean |
|-------------------------------------|--|----------------------------|----------------------------|------------------------------|----------------------------|----------------------------|--------------|
| | No Zn | 2.5 mg Zn kg ⁻¹ | 5.0 mg Zn kg ⁻¹ | No Zn | 2.5 mg Zn kg ⁻¹ | 5.0 mg Zn kg ⁻¹ | |
| Hariharapur series | | | | | | | |
| No lime | 0.40 | 1.44 | 2.95 | 0.88 | 1.68 | 3.21 | 1.92 |
| 1/10 th LR | 0.40 | 1.24 | 2.30 | 0.66 | 1.67 | 3.20 | 1.84 |
| 1/3 rd LR | 0.38 | 1.06 | 1.64 | 0.61 | 1.62 | 2.68 | 1.64 |
| 2/3 rd LR | 0.37 | 0.86 | 1.45 | 0.44 | 1.59 | 2.55 | 1.53 |
| LR | 0.34 | 0.77 | 1.25 | 0.44 | 1.27 | 2.53 | 1.41 |
| Mean | 0.38 | 1.08 | 1.92 | 0.61 | 1.57 | 2.83 | - |
| LSD (0.01) | Lime = 0.02, Zn level = 0.25, FYM level = 0.20, Lime x Zn level = 0.35, Lime x FYM level = 0.28, Zn level x FYM level = 0.47 | | | | | | |
| DTPA-Zn (mg kg ⁻¹) | | | | | | | |
| No lime | 0.78 | 1.68 | 3.85 | 1.23 | 3.70 | 5.08 | 3.34 |
| 1/10 th LR | 0.77 | 1.66 | 3.74 | 1.17 | 3.20 | 4.88 | 3.08 |
| 1/3 rd LR | 0.74 | 1.50 | 3.27 | 1.05 | 2.64 | 4.79 | 2.83 |
| 2/3 rd LR | 0.66 | 1.48 | 2.26 | 1.03 | 2.54 | 4.49 | 2.69 |
| LR | 0.51 | 1.24 | 1.92 | 0.94 | 2.54 | 4.25 | 2.58 |
| Mean | 0.69 | 1.51 | 3.01 | 1.09 | 2.92 | 4.70 | - |
| LSD (0.01) | Lime = 0.10, Zn level = 0.42, FYM level = 0.25, Lime x Zn level = 0.55, Lime x FYM level = 0.37, Zn level x FYM level = 0.70 | | | | | | |
| Mehlich 1-Zn (mg kg ⁻¹) | | | | | | | |
| No lime | 0.90 | 2.50 | 4.62 | 1.50 | 3.81 | 6.24 | 3.85 |
| 1/10 th LR | 0.89 | 2.31 | 4.61 | 1.34 | 3.72 | 6.20 | 3.75 |
| 1/3 rd LR | 0.84 | 2.25 | 4.28 | 1.33 | 3.39 | 5.68 | 3.47 |
| 2/3 rd LR | 0.84 | 2.18 | 3.94 | 1.22 | 3.05 | 5.62 | 3.30 |
| LR | 0.84 | 1.93 | 3.91 | 1.06 | 3.03 | 5.43 | 3.17 |



| | | | | | | | | |
|-----------------------|--|------|------|------|------|------|------|------|
| Mean | 0.86 | 2.23 | 4.27 | - | 1.29 | 3.40 | 5.83 | - |
| LSD (0.01) | Lime = 0.02, Zn level = 0.30, FYM level = 0.27, Lime x Zn level = 0.37, Lime x FYM level = 0.30, Zn level x FYM level = 0.60 | | | | | | | |
| | ABDTPA-Zn (mg kg ⁻¹) | | | | | | | |
| No lime | 0.71 | 2.03 | 4.06 | 2.27 | 1.16 | 2.54 | 3.98 | 2.56 |
| 1/10 th LR | 0.68 | 1.98 | 3.19 | 1.95 | 1.11 | 2.43 | 3.92 | 2.49 |
| 1/3 rd LR | 0.59 | 1.70 | 2.62 | 1.64 | 1.00 | 2.43 | 3.84 | 2.42 |
| 2/3 rd LR | 0.52 | 1.52 | 2.29 | 1.44 | 0.95 | 2.37 | 3.61 | 2.31 |
| LR | 0.49 | 1.25 | 2.12 | 1.29 | 0.93 | 2.21 | 3.31 | 2.15 |
| Mean | 0.60 | 1.70 | 2.85 | - | 1.03 | 2.40 | 3.73 | - |
| LSD (0.01) | Lime = 0.05, Zn level = 0.28, FYM level = 0.32, Lime x Zn level = 0.32, Lime x FYM level = 0.41, Zn level x FYM level = 0.62 | | | | | | | |
| | Debatoli series | | | | | | | |
| | DTPA-Zn (mg kg ⁻¹) | | | | | | | |
| No lime | 1.45 | 2.62 | 3.29 | 2.45 | 1.63 | 2.80 | 4.33 | 2.92 |
| 1/10 th LR | 1.30 | 2.32 | 2.93 | 2.18 | 1.37 | 2.54 | 4.01 | 2.64 |
| 1/3 rd LR | 1.08 | 1.94 | 2.91 | 1.98 | 1.32 | 2.37 | 3.79 | 2.49 |
| 2/3 rd LR | 0.99 | 1.78 | 2.80 | 1.86 | 1.08 | 2.25 | 2.95 | 2.09 |
| LR | 0.77 | 1.72 | 2.73 | 1.74 | 0.99 | 2.21 | 2.48 | 1.89 |
| Mean | 1.12 | 2.08 | 2.93 | - | 1.28 | 2.43 | 3.51 | - |
| LSD (0.01) | Lime = 0.21, Zn level = 0.50, FYM level = 0.35, Lime x Zn level = 0.75, Lime x FYM level = 0.78, Zn level x FYM level = 0.98 | | | | | | | |
| | Mehlich 1-Zn (mg kg ⁻¹) | | | | | | | |
| No lime | 1.73 | 3.61 | 6.78 | 4.04 | 2.64 | 4.78 | 6.78 | 4.73 |
| 1/10 th LR | 1.63 | 3.60 | 6.59 | 3.94 | 2.44 | 4.20 | 6.28 | 4.31 |
| 1/3 rd LR | 1.51 | 3.44 | 6.12 | 3.69 | 2.42 | 4.10 | 6.21 | 4.24 |
| 2/3 rd LR | 1.49 | 3.33 | 4.13 | 2.98 | 2.40 | 4.06 | 5.69 | 4.05 |
| LR | 1.26 | 3.15 | 4.06 | 2.82 | 2.37 | 3.74 | 5.46 | 3.86 |
| Mean | 1.53 | 3.43 | 5.54 | - | 2.45 | 4.18 | 6.08 | - |
| LSD (0.01) | Lime = 0.09, Zn level = 0.50, FYM level = 0.28, Lime x Zn level = 0.45, Lime x FYM level = 0.42, Zn level x FYM level = 0.85 | | | | | | | |



| 0.1 M HCl-Zn (mg kg ⁻¹) | | | | | | | | | | |
|-------------------------------------|---|------|------|------|------|------|------|------|------|--|
| No lime | 2.35 | 4.26 | 4.66 | 3.76 | 2.80 | 4.54 | 6.69 | 4.68 | 4.22 | |
| 1/10 th LR | 2.32 | 4.42 | 5.34 | 4.03 | 2.75 | 4.70 | 6.93 | 4.79 | 4.41 | |
| 1/3 rd LR | 2.22 | 4.40 | 6.07 | 4.23 | 2.86 | 5.25 | 7.61 | 5.24 | 4.74 | |
| 2/3 rd LR | 2.23 | 3.87 | 7.46 | 4.52 | 2.91 | 5.14 | 7.01 | 5.02 | 4.77 | |
| LR | 2.22 | 4.53 | 6.96 | 4.57 | 2.85 | 6.06 | 7.79 | 5.57 | 5.07 | |
| Mean | 2.27 | 4.30 | 6.10 | - | 2.83 | 5.14 | 7.21 | - | - | |
| LSD (0.01) | Lime = 0.06, Zn level = 0.35, FYM level = 0.37, Lime x Zn level = 0.45, Zn level x FYM level = 0.79 | | | | | | | | | |
| ABDTPA-Zn (mg kg ⁻¹) | | | | | | | | | | |
| No lime | 2.10 | 3.19 | 4.23 | 3.18 | 2.12 | 3.34 | 5.17 | 3.54 | 3.36 | |
| 1/10 th LR | 1.82 | 3.46 | 4.19 | 3.16 | 1.98 | 3.37 | 5.89 | 3.75 | 3.46 | |
| 1/3 rd LR | 1.61 | 2.77 | 4.60 | 2.99 | 1.93 | 3.46 | 5.17 | 3.52 | 3.26 | |
| 2/3 rd LR | 1.36 | 2.05 | 5.12 | 2.84 | 1.75 | 3.02 | 4.26 | 3.01 | 2.93 | |
| LR | 1.22 | 2.17 | 4.22 | 2.54 | 1.53 | 3.36 | 4.42 | 3.10 | 2.82 | |
| Mean | 1.62 | 2.73 | 4.47 | - | 1.86 | 3.31 | 4.98 | - | - | |
| LSD (0.01) | Lime = 0.10, Zn level = 0.35, FYM level = 0.20, Lime x Zn level = 0.47, Zn level x FYM level = 0.70 | | | | | | | | | |



Table 4 Effect of FYM, lime and Zn application on dry matter yield, Zn concentration and Zn uptake by maize.

| Treatments | No FYM | | | FYM (10 t ha ⁻¹) | | | Overall mean |
|---|--|----------------------------|----------------------------|------------------------------|----------------------------|----------------------------|--------------|
| | No Zn | 2.5 mg Zn kg ⁻¹ | 5.0 mg Zn kg ⁻¹ | No Zn | 2.5 mg Zn kg ⁻¹ | 5.0 mg Zn kg ⁻¹ | |
| Hariharapur series | | | | | | | |
| No lime | 1.64 | 2.02 | 2.04 | 1.90 | 2.06 | 2.23 | 2.30 |
| 1/10 th LR | 2.43 | 2.37 | 2.16 | 2.32 | 2.21 | 2.66 | 2.53 |
| 1/3 rd LR | 2.88 | 2.87 | 2.96 | 2.83 | 2.57 | 3.66 | 2.98 |
| 2/3 rd LR | 2.65 | 2.37 | 2.66 | 2.64 | 2.40 | 3.01 | 2.66 |
| LR | 1.77 | 2.06 | 2.52 | 2.12 | 1.94 | 2.71 | 2.23 |
| Mean | 2.27 | 2.34 | 2.47 | - | 2.23 | 2.85 | - |
| LSD (0.01) | Lime = 0.30, Zn level = 0.11, FYM level = 0.25, Lime x Zn level = 0.50, Lime x FYM level = 0.61, Zn level x FYM level = 0.42 | | | | | | |
| Zn concentration (mg kg ⁻¹) | | | | | | | |
| No lime | 54.0 | 84.0 | 112 | 83.3 | 57.4 | 104 | 93.2 |
| 1/10 th LR | 53.3 | 87.4 | 113 | 84.6 | 59.2 | 99.5 | 92.7 |
| 1/3 rd LR | 38.5 | 63.5 | 75.0 | 59.0 | 46.3 | 72.8 | 66.4 |
| 2/3 rd LR | 27.4 | 52.7 | 60.8 | 47.0 | 35.4 | 59.8 | 54.2 |
| LR | 25.2 | 44.8 | 54.2 | 41.4 | 31.2 | 48.9 | 46.1 |
| Mean | 39.7 | 66.5 | 83.0 | - | 45.9 | 76.9 | 88.8 |
| LSD (0.01) | Lime = 3.50, Zn level = 0.11, FYM level = 2.00, Lime x Zn level = 3.21, Lime x FYM level = 5.70, Zn level x FYM level = 3.15 | | | | | | |
| Zn uptake (mg pot ⁻¹) | | | | | | | |
| No lime | 0.11 | 0.14 | 0.23 | 0.16 | 0.12 | 0.27 | 0.22 |
| 1/10 th LR | 0.13 | 0.21 | 0.24 | 0.19 | 0.13 | 0.27 | 0.24 |
| 1/3 rd LR | 0.10 | 0.18 | 0.22 | 0.17 | 0.11 | 0.21 | 0.20 |
| 2/3 rd LR | 0.08 | 0.13 | 0.16 | 0.12 | 0.09 | 0.14 | 0.15 |



| | | | | | | | | | |
|---|--|------|------|------|------|------|------|------|------|
| LR | 0.05 | 0.09 | 0.14 | 0.09 | 0.06 | 0.10 | 0.16 | 0.11 | 0.10 |
| Mean | 0.09 | 0.15 | 0.20 | - | 0.10 | 0.20 | 0.25 | - | - |
| LSD (0.01) | Lime = 0.002, Zn level = 0.005, FYM level = 0.004, Lime x Zn level = 0.008, Lime x FYM level = 0.007, Zn level x FYM level = 0.012 | | | | | | | | |
| Debatoli series | | | | | | | | | |
| No lime | 2.84 | 3.55 | 4.19 | 3.53 | 3.45 | 3.72 | 3.44 | 3.57 | 3.55 |
| 1/10 th LR | 3.37 | 3.94 | 4.52 | 3.94 | 3.56 | 4.06 | 4.21 | 3.91 | 3.93 |
| 1/3 rd LR | 3.71 | 4.32 | 4.54 | 4.19 | 3.80 | 4.84 | 4.46 | 4.37 | 4.28 |
| 2/3 rd LR | 3.55 | 3.67 | 4.43 | 3.88 | 3.53 | 3.74 | 3.76 | 3.68 | 3.78 |
| LR | 3.27 | 3.54 | 3.46 | 3.42 | 3.46 | 3.59 | 3.55 | 3.54 | 3.48 |
| Mean | 3.35 | 3.80 | 4.23 | - | 3.56 | 3.99 | 3.88 | - | - |
| LSD (0.01) | Lime = 0.32, Zn level = 0.22, FYM level = ns, Lime x Zn level = 0.58, Lime x FYM level = ns, Zn level x FYM level = ns | | | | | | | | |
| Zn concentration (mg kg ⁻¹) | | | | | | | | | |
| No lime | 62.2 | 85.0 | 119 | 88.7 | 71.0 | 86.2 | 126 | 94.4 | 91.6 |
| 1/10 th LR | 60.4 | 78.4 | 105 | 81.3 | 70.7 | 84.3 | 116 | 90.3 | 85.8 |
| 1/3 rd LR | 55.3 | 68.9 | 94.8 | 73.0 | 71.6 | 77.3 | 97.9 | 82.3 | 77.6 |
| 2/3 rd LR | 47.8 | 66.5 | 75.2 | 63.2 | 52.4 | 69.5 | 80.2 | 67.4 | 65.3 |
| LR | 39.7 | 60.6 | 64.8 | 55.0 | 44.8 | 62.6 | 70.6 | 59.4 | 57.2 |
| Mean | 53.1 | 71.9 | 91.8 | - | 62.1 | 76.0 | 98.1 | - | - |
| LSD (0.01) | Lime = 1.80, Zn level = 0.20, FYM level = 1.50, Lime x Zn level = 2.10, Lime x FYM level = 3.80, Zn level x FYM level = 2.10 | | | | | | | | |
| Zn uptake (mg pot ⁻¹) | | | | | | | | | |
| No lime | 0.18 | 0.30 | 0.50 | 0.33 | 0.25 | 0.32 | 0.44 | 0.34 | 0.33 |
| 1/10 th LR | 0.20 | 0.31 | 0.47 | 0.33 | 0.24 | 0.34 | 0.49 | 0.36 | 0.34 |
| 1/3 rd LR | 0.21 | 0.30 | 0.43 | 0.31 | 0.27 | 0.37 | 0.44 | 0.36 | 0.34 |
| 2/3 rd LR | 0.17 | 0.24 | 0.33 | 0.25 | 0.19 | 0.26 | 0.30 | 0.25 | 0.25 |
| LR | 0.13 | 0.21 | 0.23 | 0.19 | 0.15 | 0.23 | 0.25 | 0.21 | 0.20 |
| Mean | 0.18 | 0.27 | 0.39 | - | 0.22 | 0.30 | 0.38 | - | - |
| LSD (0.01) | Lime = 0.03, Zn level = 0.11, FYM level = 0.02, Lime x Zn level = ns, Lime x FYM level = 0.08, Zn level x FYM level = ns | | | | | | | | |



Table 5 Pearson's correlation coefficient values revealing relationship among soil properties, dry matter yield, Zn concentration, Zn uptake and extracted Zn in soils (n = 90).

| | pH | EC | OC | Dry matter yield | Zn conc. | Zn uptake | DTPA-Zn | Mehlich 1-Zn | 0.1 M HCl-Zn | ABDTPA-Zn |
|--------------------|----------|--------|---------|------------------|----------|-----------|---------|--------------|--------------|-----------|
| Hariharapur series | | | | | | | | | | |
| pH | 1 | | | | | | | | | |
| EC | 0.058 | 1 | | | | | | | | |
| OC | -0.089 | -0.084 | 1 | | | | | | | |
| Dry matter yield | 0.059 | 0.093 | 0.221* | 1 | | | | | | |
| Zn conc. | -0.590** | -0.029 | 0.232* | 0.047 | 1 | | | | | |
| Zn uptake | -0.397** | 0.036 | 0.294** | 0.605** | 0.792** | 1 | | | | |
| DTPA-Zn | 0.010 | -0.073 | 0.211* | 0.391** | 0.610** | 0.523** | 1 | | | |
| Mehlich 1-Zn | 0.130 | -0.045 | 0.272** | 0.281** | 0.510** | 0.545** | 0.897** | 1 | | |
| 0.1 M HCl-Zn | 0.046 | -0.076 | 0.242* | 0.260* | 0.633** | 0.626** | 0.871** | 0.929** | 1 | |
| ABDTPA-Zn | -0.011 | -0.013 | 0.136 | 0.285** | 0.656** | 0.673** | 0.887** | 0.922** | 0.923** | 1 |
| Debatoli series | | | | | | | | | | |
| pH | 1 | | | | | | | | | |
| EC | 0.032 | 1 | | | | | | | | |
| OC | 0.113 | -0.098 | 1 | | | | | | | |
| Dr matter yield | -0.154 | 0.096 | 0.011 | 1 | | | | | | |
| Zn conc. | -0.343** | 0.042 | 0.158 | 0.384** | 1 | | | | | |
| Zn uptake | -0.326** | 0.086 | 0.110 | 0.727** | 0.905** | 1 | | | | |
| DTPA-Zn | -0.087 | 0.061 | 0.290** | 0.133 | 0.741** | 0.715** | 1 | | | |
| Mehlich 1-Zn | 0.168 | 0.091 | 0.317** | 0.330** | 0.589** | 0.568** | 0.811** | 1 | | |
| 0.1 M HCl-Zn | 0.188 | 0.130 | 0.294** | 0.333** | 0.562** | 0.545** | 0.822** | 0.937** | 1 | |
| ABDTPA-Zn | -0.074 | 0.108 | 0.193 | 0.419** | 0.772** | 0.748** | 0.889** | 0.890** | 0.887** | 1 |

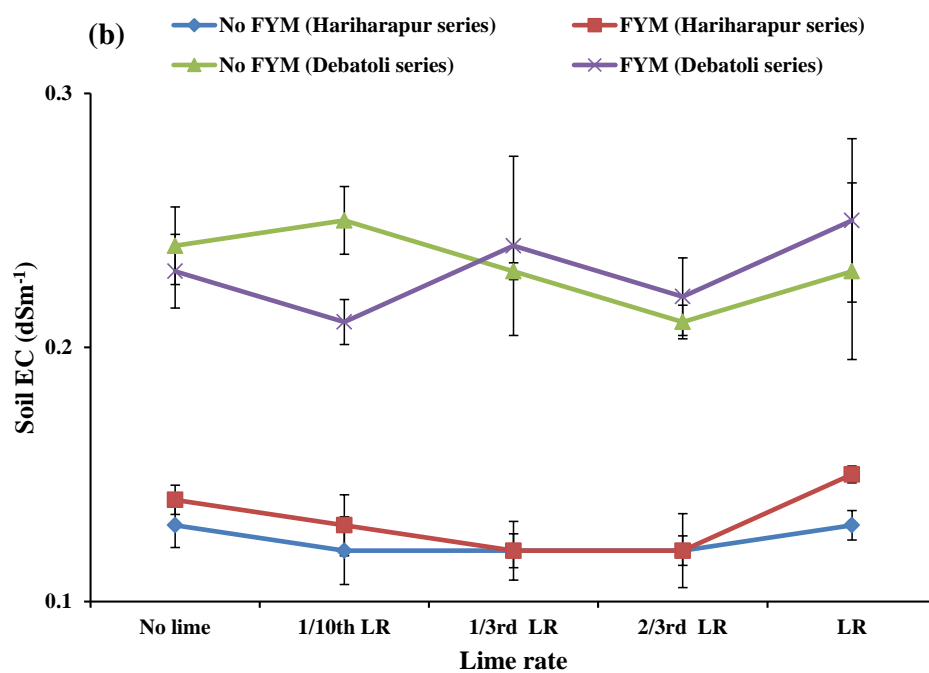
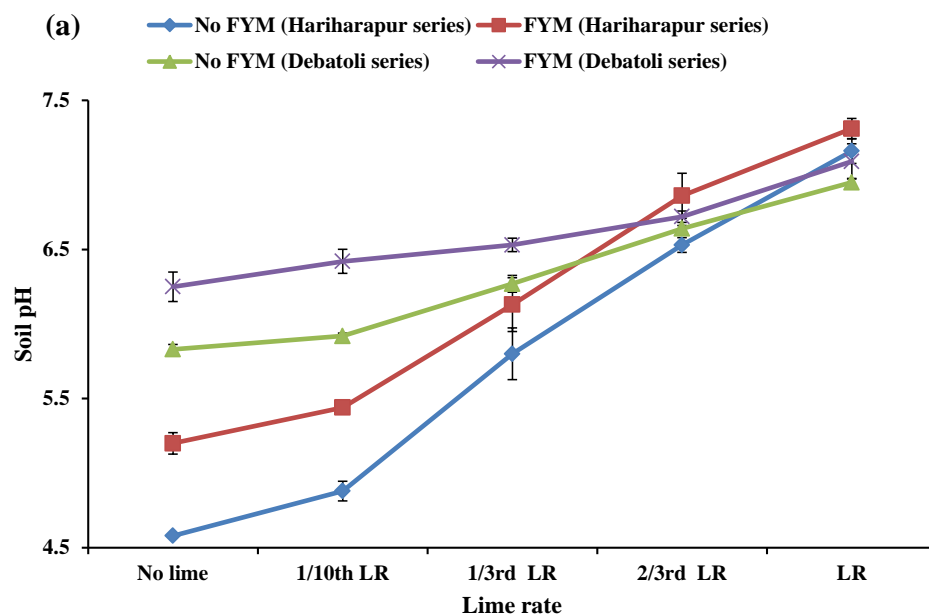
*p ≤ 0.05, **p ≤ 0.01.



Fig. 1. Soil pH, EC and OC as influenced by interaction of Zn application and lime rate in Hariharapur and Debatoli series. Error bars represent \pm SE.

Fig. 2. Extractable Zn by different extractants as influenced by interaction of Zn application and lime rate in Hariharapur and Debatoli series. Error bars represent \pm SE.

Fig. 3. Dry matter yield, Zn concentration and Zn uptake by maize as influenced by interaction of Zn application and lime rate in Hariharapur and Debatoli series. Error bars represent \pm SE.



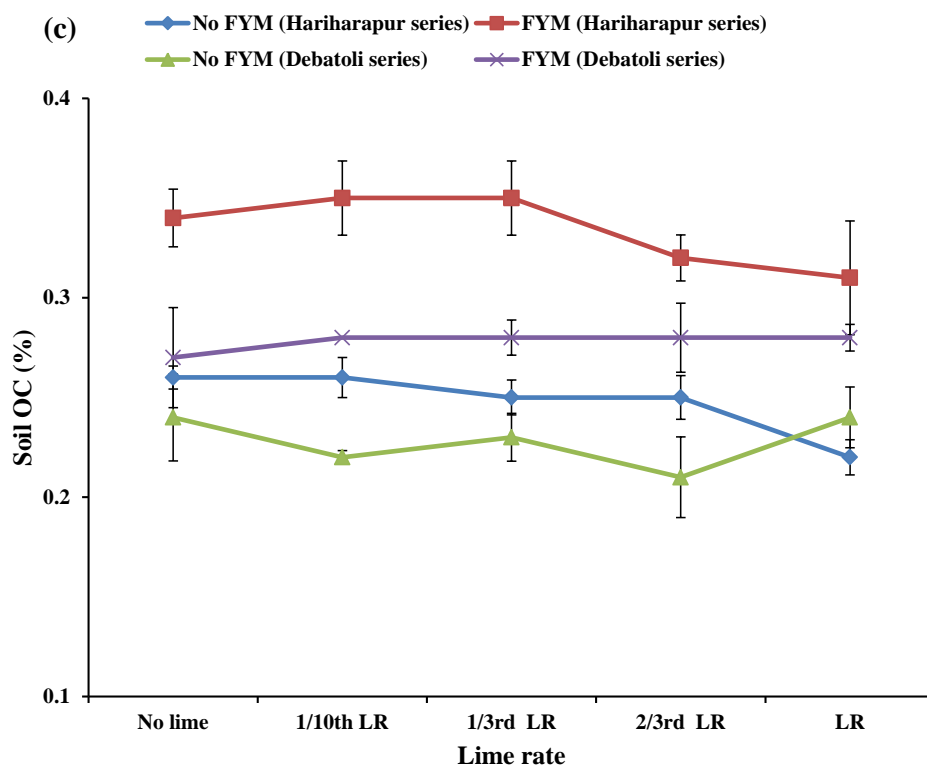
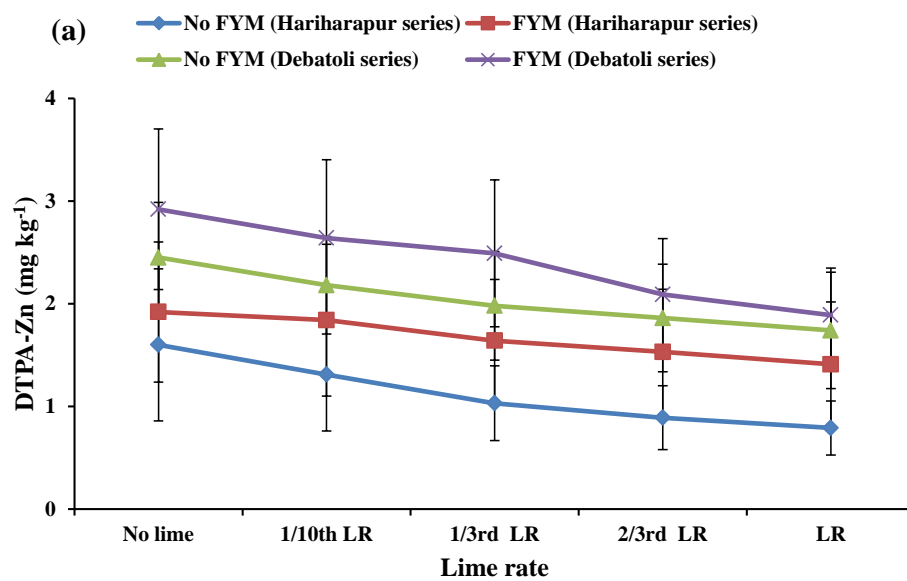
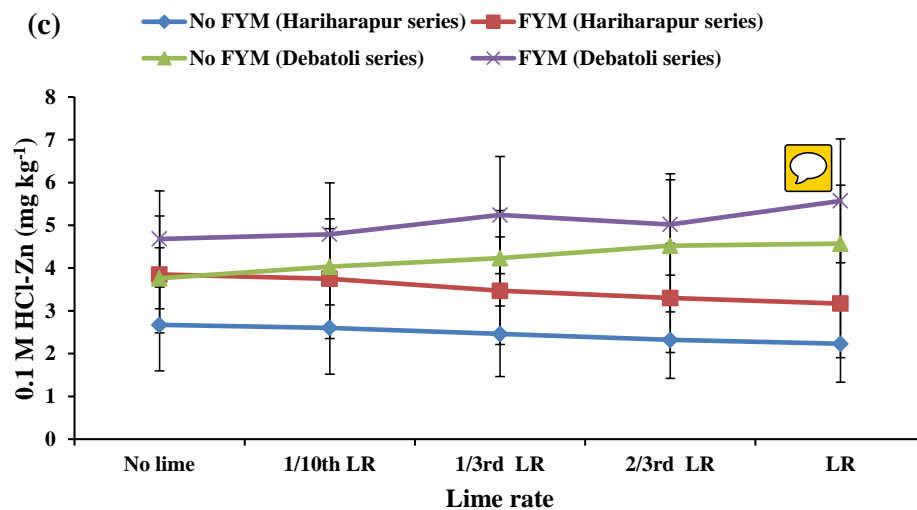
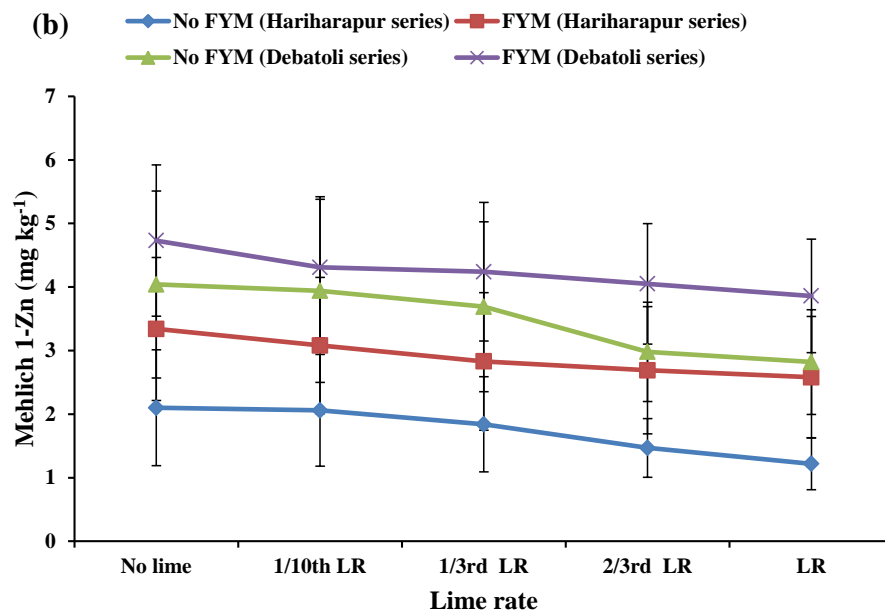


Fig. 1. Soil pH, EC and OC as influenced by interaction of Zn application and lime rate in Hariharapur and Debatoli series. Error bars represent \pm SE.





(d)

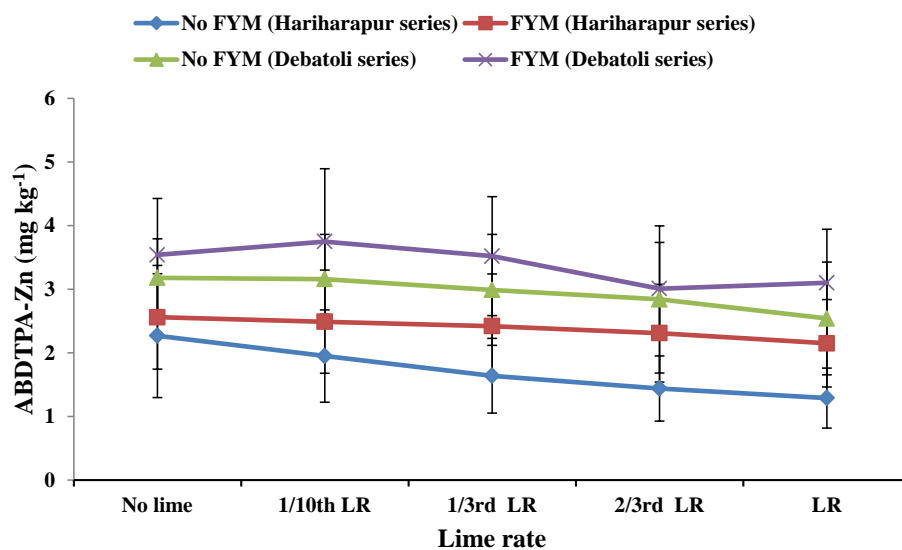
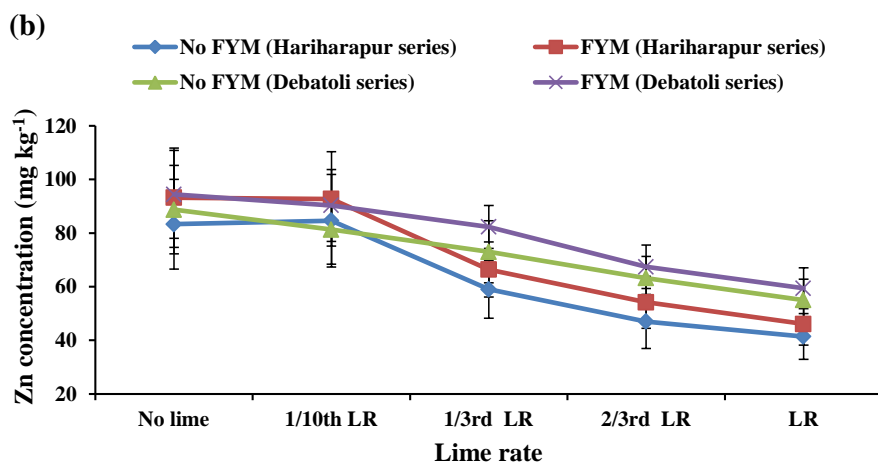
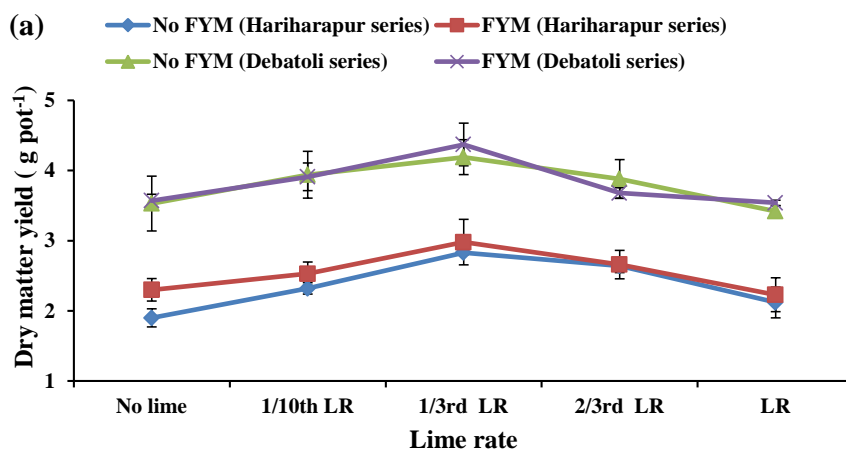


Fig. 2. Extractable Zn by different extractants as influenced by interaction of Zn application and lime rate in Hariharapur and Debatoli series. Error bars represent \pm SE.



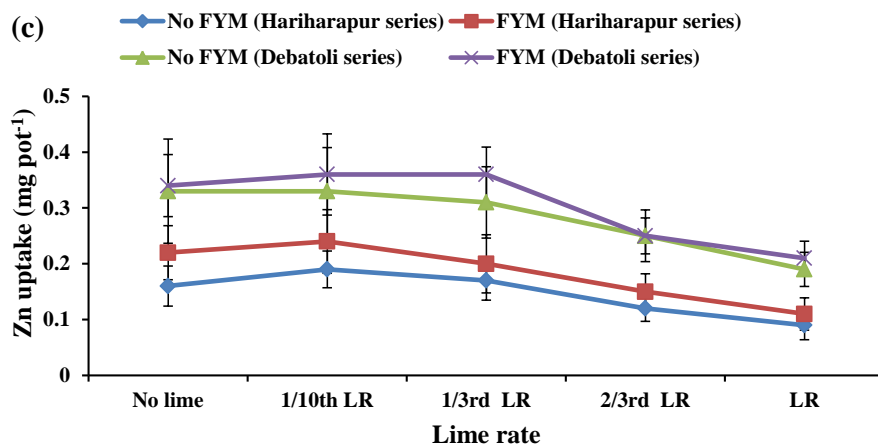


Fig. 3. Dry matter yield, Zn concentration and Zn uptake by maize as influenced by interaction of Zn application and lime rate in Hariharapur and Debatoli series. Error bars represent \pm SE.