International Journal of Ecology and Environmental Sciences 42 (1): 55-62, 2016
ISSN: 2320-5199 (Online)

Periodic Changes in Available Micronutrient Cations under Submerged Condition in a *Mollisol* Treated with Zinc Incubated with Low Doses of Organics

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ABSTRACT

An incubation study was conducted to examine the effect of zinc fertilizer and low doses (200 kg ha^{-1}) of farm manure and fresh cow dung on the periodic changes in the availability of micronutrient cations under submerged conditions. The contents of diethylene triamine pentaacetic acid (DTPA) extractable micronutrient cations were recorded throughout the incubation period and were found to rise during early periods but declined at later stages of incubation. Application of FYM increased the contents of DTPA extractable Zn, Cu and Mn significantly while application of fresh cow dung was more effective in increasing DTPA extractable all micronutrient cations except Zn which was significantly decreased. Application of Zn fertilizer increased the content of DTPA extractable Zn but significantly decreased the extractable Mn. A significant effect of three factor interaction involving time x Zn level x type of organics revealed that application of organics especially fresh cow dung was effective in increasing DTPA extractable Fe and Mn during the early stages of submergence.

Key Words: DTPA extractable Iron; Zinc; Copper; Manganese

INTRODUCTION

The use of Zn fertilizer in rice crops is very common under rice-wheat rotation in Northern India due to large scale deficiency of this micronutrient in soil and a relatively higher response as compared to wheat. The amount of Zn needed by rice crop is to the tune of only to 200-250 g Zn ha^{-1} however, the rate at which Zn fertilizers are applied is around 2.5-5.0 kg Zn ha^{-1} as a large proportion of it is fixed by soil through irreversible adsorption. The availability of soil adsorbed Zn also decreases with time (Boawn 1974, Armour et al. 1989). Organic manures increase the availability of Zn to crops (Sharma and Deb 1991, Kumar et al. 1999) directly by contributing through their Zn content and indirectly through the formation of organic complexes which have higher availability in soil and are also subjected to lesser inactivation through irreversible adsorption on soil mineral fractions. However, one of the serious practical difficulties in the Indian context is the low availability of organic manures with the farmers. This led to a hypothesis that if low quantities of organic manures are incubated with $ZnSO_4$ those could improve the supply of Zn in submerged soils. An incubation study was, therefore, planned to examine the periodic changes in the contents of DTPA extractable micronutrient cations in a submerged soil which has received varying levels of Zn incubated with low quantities of organics.

MATERIALS AND METHODS

A pot experiment was conducted at Department of Soil Science, of G.B. Pant University of Agriculture and Technolgy, Pantnagar, District Udham Singh Nagar, Uttarakhand, India. A bulk sample of surface (0-15 cm) soil was collected from Crop Research Centre (C.R.C.), Pantnagar. The soil sample was air dried, crushed with a wooden roller and passed through a sieve having 2 mm openings. The soil had silty clay loam texture, 6.45 pH and 0.34 dSm^{-1} electrical conductivity in 1:2 soil water suspension, 17.3 g organic carbon, DTPA (pH 7.3) extractable 0.57 mg Zn; 1.24 mg Cu; 25.39 mg Fe and 13.79 mg kg^{-1} soil.

Two kg soil sample each was filled in thirty six plastic pots. The treatments were: T_1-Control, T_2- 1.25 kg Zn ha^{-1}, T_3- 2.5 kg Zn ha^{-1}, T_1- T_4- 5.0 kg Zn ha^{-1}, T_5- 200 kg Farm Yrad Manure (FYM) ha^{-1}, T_6- 1.25 kg Zn + 200 kg FYM ha^{-1}, T_7- 2.5 kg Zn + 200 kg FYM ha^{-1}, T_8- 5.0 kg Zn + 200 kg FYM ha^{-1}, T_9- 200 kg Fresh Cow Dung (FCD) ha^{-1}, T_{10}- 1.25 kg Zn + 200 kg FCD ha^{-1}, T_{11}- 2.5 kg Zn + 200 kg FCD ha^{-1}, T_{12}- 5.0 kg Zn + 200 kg FCD ha^{-1}. For treatments T_5 to T_{12}, the required quantities of Zn as $ZnSO_4.7H_2O$ were weighed and thoroughly mixed with the FYM or fresh cow dung and incubated at room temperature at 30% moisture content for 1 month. Thereafter, these treatments were applied to pots in triplicate and thoroughly mixed with soil. After treatment application, all pots were flooded with water up to five cm. Soil samples were taken from these pots at different interval *viz:* 1 WAI (week after incubation), 2 WAI, 5 WAI, 9 WAI. An aliquot of thoroughly mixed soil sample was weighed, dried in an electric oven at 105±5ºC temperature for moisture determination. A separate aliquot of 10 g moist soil was used for analysis of DTPA (pH 7.3) extractable micronutrient cations (Lindsay and Norvell 1978) by atomic absorption spectrophotometer. The contents of DTPA extractable micronutrient cations in soil were calculated on oven dry weight basis.

RESULTS AND DISCUSSION

DTPA extractable Zn

The data on the effect of different treatments on the DTPA extractable zinc content in soil at different time intervals are presented in Table 1.As regards the main effect of time of incubation on the content of DTPA extractable Zn, the content was highest at 1 WAI (week after incubation) but declined sharply reaching to the lowest level at 5 WAI.

At 9 WAI the DTPA extractable Zn content again increased in comparison to the value at 5 WAI but remained lower as compared to the content at 1 WAI. Singh et al. (1992) conducted an experiment to study the kinetics of DTPA extractable micronutrients in soil incubated with organic manures. They also reported that the content of DTPA extractable micronutrients was increased slightly during first week of incubation. The content of Zn started declining thereafter and this trend continued up to 12 weeks of incubation.

The main effect of organic manures application revealed that the content of DTPA extractable Zn was significantly increased by 8.3 percent with application of low dose (200 kg FYM ha^{-1}) in comparison to no application of FYM. Nambair (1994) also reported from the long-term experiments (LTFE) that application of 15 t FYM ha^{-1} annum-^{1} for 16 years either built up or maintained the available Zn status. However, application of an equivalent amount of fresh cow dung manure significantly decreased the content of DTPA extractable zinc by 14.39 percent in comparison to no application of organic manure.

The main effect of zinc level indicated that application of zinc @ 1.25, 2.5, and 5.0 kg Zn ha^{-1} increased the content of DTPA extractable zinc significantly by 15.1, 19.8 and 53.8 percent, respectively over no application of Zn. Sakal et al. (1981) reported that $ZnSO_4$ application raised the available Zn in soil and left a substantial amount of Zn for the succeeding crop. However, Zn application did not affect the availability of Cu and Mn in soil.

The interaction effect of time of incubation and organic manure application significantly influenced the DTPA extractable zinc content of soil. A close perusal of data indicated that the content of DTPA extractable Zn

Table 1. Effect of time of incubation on DTPA-extractable Zn-content under different treatments.

Treatments	Zn concentration ($mg\ kg^{-1}$)				
Time of incubation	1W	2W	5W	9W	Zn × M
T_1 (Control)	1.53	1.12	0.70	1.10	1.11
T_2 (1.25 kg Zn ha^{-1})	1.40	1.08	1.06	0.99	1.13
T_3 (2.5 kg Zn ha^{-1})	1.67	1.07	0.68	1.38	1.20
T_4 (5.0 kg Zn ha^{-1})	2.38	1.62	1.30	2.06	1.84
T × M Mean	1.74	1.22	0.94	1.38	1.32
T_5 (200 kg FYM ha^{-1})	1.61	1.08	1.01	1.13	1.21
T_6 (1.25 kg Zn + 200 kg FYM ha^{-1})	1.89	1.05	1.14	1.52	1.40
T_7 (2.5 kg Zn + 200 kg FYM ha^{-1})	1.98	1.20	1.00	1.05	1.31
T_8 (5.0 kg Zn + 200 kg FYM ha^{-1})	2.40	1.73	1.05	2.00	1.80
T × M Mean	1.97	1.27	1.05	1.43	1.43
T_9 (200 kg Fresh cowdung ha^{-1})	1.23	0.61	0.81	0.82	0.87
T_{10} (1.25 kg Zn + 200 kg Fresh cowdung ha^{-1})	1.78	0.71	1.00	0.96	1.11
T_{11} (2.5 kg Zn + 200 kg Fresh cowdung ha^{-1})	1.94	0.92	1.22	1.08	1.29
T_{12} (5.0 kg Zn + 200 kg Fresh cowdung ha^{-1})	1.94	1.03	0.74	1.31	1.25
T × M Mean	1.72	0.82	0.95	1.04	1.13
T × Zn Mean					
0	1.46	0.94	0.84	1.02	1.06
1.25	1.69	0.94	1.07	1.16	1.22
2.5	1.86	1.06	0.97	1.17	1.27
5.0	2.24	1.46	1.03	1.79	1.63
T Mean	1.81	1.10	0.98	1.28	1.29

Effect	T	M	Zn	T × M	Zn × M	T × Zn	T × M × Zn
S.Em.	0.044	0.038	0.044	0.076	0.087	0.076	0.15
C. D. (p=0.05)	0.12	0.11	0.12	0.24	NS	0.21	NS

at 9 WAI under no application of organic manure and application of FYM significantly increased as compared with the values at 5WAI. However, with the application of FCD such increase was statistically non-significant.

The interaction effect of time and zinc significantly increased the content of DTPA extractable zinc, it was noted that the increase in content of DTPA extractable Zn at 9WAI compared with that at 5WAI was significant only at the highest level of Zn application (5 kg Zn ha^{-1}). The interaction effect of zinc x organic manure and time x manure x zinc had no statistically significant effect on DTPA extractable Zn-content of soil.

DTPA extractable Cu

The data on the effect of different treatments on DTPA extractable Cu content in soil at different time intervals are presented in Table 2. The main effect of time of incubation indicated that the content of DTPA extractable Cu was the highest at 1 WAI (week after incubation) and then it declined sharply reaching to the lowest level at 5 WAI and thereafter, it again increased at 9 WAI but remained lower in comparison to the content at 1 WAI.

The main effect of organic manure application revealed that the content of DTPA extractable Cu was not significantly increased with application of low doses of FYM (200 kg FYM ha^{-1}) in comparison to no application of FYM while the application of an equivalent amount of FCD significantly increased the content of DTPA extractable Cu by 41.81 percent in comparison to no application of organic manure. Qian et al. (2003) studied Cu and Zn distribution in soil as influenced by application of animal manure in east-central Saskatchewan. They also reported that the highest level of swine manure addition led to a small but significant increase in DTPA extractable Cu in the field cropland.

The main effect of zinc had no significant effect on the DTPA extractable Cu content of soil. The interaction

Table 2. Effect of time of incubation on DTPA-extractable Cu-content under different treatments.

Treatments			Cu concentration ($mg\ kg^{-1}$)		
Time of incubation	1W	2W	5W	9W	Zn × M
T_1 (Control)	2.84	1.88	1.08	2.80	2.15
T_2 (1.25 kg Zn ha^{-1})	3.53	2.10	1.25	2.89	2.44
T_3 (2.5 kg Zn ha^{-1})	3.69	2.21	0.58	3.06	2.38
T_4 (5.0 kg Zn ha^{-1})	3.16	1.80	0.62	3.58	2.29
T × M Mean	3.31	2.00	0.88	3.08	2.32
T_5 (200 kg FYM ha^{-1})	4.33	2.20	1.09	2.36	2.49
T_6 (1.25 kg Zn + 200 kg FYM ha^{-1})	3.44	1.74	1.09	2.93	2.30
T_7 (2.5 kg Zn + 200 kg FYM ha^{-1})	3.64	1.85	1.03	2.26	2.20
T_8 (5.0 kg Zn + 200 kg FYM ha^{-1})	3.62	1.92	1.30	3.77	2.65
T × M Mean	3.76	1.93	1.13	2.83	2.41
T_9 (200 kg Fresh cowdung ha^{-1})	4.21	2.51	2.79	3.89	2.35
T_{10} (1.25 kg Zn + 200 kg Fresh cowdung ha^{-1})	4.41	2.20	2.30	3.72	3.16
T_{11} (2.5 kg Zn + 200 kg Fresh cowdung ha^{-1})	4.45	2.51	2.67	3.99	3.41
T_{12} (5.0 kg Zn + 200 kg Fresh cowdung ha^{-1})	3.73	2.18	3.02	4.09	3.25
T × M Mean	4.20	2.35	2.70	3.92	3.29
T × Zn Mean					
0	3.79	2.20	1.65	3.02	2.67
1.25	3.79	2.01	1.55	3.18	2.63
2.5	3.93	2.19	1.43	3.10	2.66
5.0	3.50	1.96	1.65	3.82	2.73
T Mean	3.75	2.09	1.57	3.28	2.67

Effect	T	M	Zn	T × M	Zn × M	T × Zn	T × M × Zn
S.Em.	0.12	0.11	0.12	0.21	0.24	0.21	0.42
C. D. (p=0.05)	0.33	0.29	NS	NS	NS	NS	NS

effect of time x manure, manure x zinc, time x zinc and time x manure x zinc also had no significant influence on DTPA extractable Cu content of soil.

DTPA extractable Fe

The data on the effect of different treatments on DTPA extractable Fe content in soil at different time intervals are presented in Table 3.

The main effect of time of incubation indicated that the content of DTPA extractable Fe was the highest at 1 WAI and then it declined sharply reaching to the lowest level at 5 WAI however, later it again increased at 9 WAI in comparison to the value at 5 WAI but remained still lower in comparison to the content at 1 WAI. Singh *et al.* (1992) conducted an experiment to study the kinetics of DTPA extractable micronutrients in soil incubated with organic manures and reported that the content of DTPA extractable micronutrients increased slightly during first week of incubation. The content of DTPA extractable Fe continued to increase up to 4 weeks of incubation and decreased thereafter. The variation in time interval for peak concentration of Fe in the present investigation and the one reported by Singh et al. (1992) could be ascribed to the differences in the nature of soil and organic carbon content.

The main effect of organic manure application revealed that the content of DTPA extractable Fe was significantly increased by 33.06 percent with application of low doses of fresh cow dung (200 kg FCD ha^{-1}). The application of 200 kg FYM ha^{-1} also increased the content of DTPA extractable Fe but the magnitude of increase was statistically non-significant. The main effect of zinc levels had no significant influence on the content of DTPA extractable Fe in the soil.

The interaction effect of time of incubation and organic manure (T x M) had significant effect on the DTPA extractable Fe content of soil. The data revealed that at the start of incubation (1 week) the content of DTPA extractable Fe was higher under both FYM and

Table 3. Effect of time of incubation on DTPA-extractable Fe-content under different treatments.

Treatments	Fe concentration (mg kg^{-1})				
Time of incubation	1W	2W	5W	9W	Zn × M
T_1 (Control)	80.00	49.51	53.70	42.50	56.43
T_2 (1.25 kg Zn ha^{-1})	83.62	72.38	48.34	76.74	70.27
T_3 (2.5 kg Zn ha^{-1})	90.74	61.75	28.20	79.98	65.16
T_4 (5.0 kg Zn ha^{-1})	83.09	54.43	21.14	94.52	63.29
T × M Mean	84.36	59.52	37.84	73.43	63.79
T_5 (200 kg FYM ha^{-1})	103.16	74.42	43.53	51.74	68.21
T_6 (1.25 kg Zn + 200 kg FYM ha^{-1})	92.39	53.43	39.43	72.87	64.53
T_7 (2.5 kg Zn + 200 kg FYM ha^{-1})	93.61	58.47	36.41	42.25	57.69
T_8 (5.0 kg Zn + 200 kg FYM ha^{-1})	92.49	49.66	40.25	87.25	67.41
T × M Mean	95.41	58.99	39.90	63.53	64.46
T_9 (200 kg Fresh cowdung ha^{-1})	104.97	75.54	67.05	78.66	81.56
T_{10} (1.25 kg Zn + 200 kg Fresh cowdung ha^{-1})	109.54	64.61	79.77	73.34	81.82
T_{11} (2.5 kg Zn + 200 kg Fresh cowdung ha^{-1})	104.72	60.79	72.28	96.28	83.52
T_{12} (5.0 kg Zn + 200 kg Fresh cowdung ha^{-1})	95.71	53.25	62.01	95.64	76.65
T × M Mean	103.74	63.55	70.28	85.98	80.89
T × Zn Mean					
0	96.05	66.49	54.76	57.63	68.73
1.25	95.18	63.47	55.85	74.32	72.20
2.5	96.35	60.34	45.63	72.84	68.79
5.0	90.43	52.45	41.13	92.47	69.12
T Mean	94.50	60.69	49.34	74.31	69.71

Effect	T	M	Zn	T × M	Zn × M	T × Zn	T × M × Zn
S.Em.	1.36	1.18	1.36	2.35	2.72	2.35	4.71
C. D. (p=0.05)	3.81	3.31	NS	6.61	7.64	6.61	13.22

FCD treatments as compared to no application of organic manure. At subsequent time intervals, the content of DTPA extractable Fe in treatments receiving FYM or no application of organic manure remained similar except for the values at 9 WAI whereas, FYM receiving treatments had the values significantly lower in comparison to the treatment receiving no organic manure. The treatments receiving FCD invariably maintained significantly higher content of DTPA extractable Fe as compared to no application of organic manure. However the differences were statistically non-significant at 2 weeks. The interaction effect of zinc levels and organic manure application (Z x M) also influenced DTPA extractable Fe-content of soil significantly. In the absence of organic manure, application of lower zinc levels (1.25 and 2.5 kg Zn ha^{-1}) had significant higher DTPA extractable Fe as compared to 0 kg Zn ha^{-1} level. However, in the presence of 200 kg FYM ha^{-1} the contents of DTPA extractable Fe under different Zn levels were statistically at par except for the values at 2.5 kg Zn ha^{-1} level which was significantly lower as compared to 0 kg Zn ha^{-1} level. In the presence of 200 kg FCD ha^{-1} also, the contents of DTPA extractable Fe at different Zn levels were statistically at par. Mukhopadhyay et al. (2001) studied the effect of organic manure, lime and Zn application on the availability of Fe in acid soil under submergence. They also reported an initial increase of extractable Fe content with the progress of submergence followed by a decreasing trend for the subsequent time intervals.

The interaction effect of time of incubation and zinc levels (T x Zn) significantly influenced the content of DTPA extractable iron. In general, the content of DTPA extractable Fe at 2 WAI and 5 WAI under relatively higher Zn levels was significantly lower as

Table 4. Effect of time of incubation on DTPA-extractable Mn-content under different treatments.

Treatments	Mn concentration ($mg\ kg^{-1}$)				
Time of incubation	1W	2W	5W	9W	Zn × M
T_1 (Control)	26.63	37.28	46.27	23.86	34.26
T_2 (1.25 kg Zn ha^{-1})	38.46	16.75	27.49	16.31	24.75
T_3 (2.5 kg Zn ha^{-1})	44.31	13.35	11.05	8.44	19.29
T_4 (5.0 kg Zn ha^{-1})	29.94	15.30	11.33	14.02	17.65
T × M Mean	35.59	20.67	24.04	15.66	23.99
T_5 (200 kg FYM ha^{-1})	50.37	18.86	17.78	7.55	23.64
T_6 (1.25 kg Zn + 200 kg FYM ha^{-1})	46.61	12.89	19.97	16.39	23.96
T_7 (2.5 kg Zn + 200 kg FYM ha^{-1})	50.44	65.91	17.40	8.72	35.62
T_8 (5.0 kg Zn + 200 kg FYM ha^{-1})	59.55	46.77	26.45	22.53	36.33
T × M Mean	49.24	36.11	20.40	13.80	29.89
T_9 (200 kg Fresh cowdung ha^{-1})	58.89	69.59	22.97	20.68	43.03
T_{10} (1.25 kg Zn + 200 kg Fresh cowdung ha^{-1})	56.90	67.46	42.05	21.79	47.05
T_{11} (2.5 kg Zn + 200 kg Fresh cowdung ha^{-1})	60.95	61.18	53.18	31.21	53.13
T_{12} (5.0 kg Zn + 200 kg Fresh cowdung ha^{-1})	52.14	60.04	26.06	27.47	41.43
T × M Mean	57.22	66.07	36.06	25.28	46.16
T × Zn Mean					
0	46.30	41.91	29.01	17.36	33.64
1.25	47.32	32.36	29.83	18.16	31.92
2.5	51.90	48.81	27.21	16.12	36.01
5.0	43.88	40.70	21.28	21.34	31.80
T Mean	47.35	40.95	26.83	18.25	33.34

Effect	T	M	Zn	T × M	Zn × M	T × Zn	T × M × Zn
S.Em.	0.51	0.44	0.51	0.87	1.01	0.87	1.75
C. D. (p=0.05)	1.41	1.22	1.41	2.45	2.82	2.45	4.90

compared to the values at 0 kg Zn ha^{-1} level. At a later stage (9WAI), the trend was reversed and DTPA extractable Fe content in treatments receiving Zn levels had higher level of DTPA extractable Fe In comparison to the value at 0 kg Zn ha^{-1} level.

The three factor interaction (T x Zn x M) also significantly influenced DTPA extractable Fe content in soil. In general, application of FYM and especially, of FCD resulted in higher levels of DTPA extractable Fe during early stages and also at the end of incubation.

DTPA extractable Mn

The data on the effect of different treatments on DTPA extractable Mn content in soil at different time intervals are presented in Table 4.

The main of time of incubation significantly influenced the DTPA extractable Mn content of soil. The DTPA extractable soil Mn content was the highest at 1 WAI and thereafter, it declined sharply up to 9 WAI. Singh et al. (1992) studied the kinetics of DTPA extractable micronutrients in soil incubated with organic manures and reported that the content of DTPA extractable micronutrients increased slightly during first week of incubation. The content of DTPA extractable Mn continued to increase up to 4 weeks of incubation and decreased thereafter. The differences between the observations of the present investigation and those of Singh et al. (1992) could be attributed to the variation in the nature of soil and organic C content of the soil used in the study.

Mainly, the organic manure application influenced significantly the DTPA-extractable Mn of soil. The DTPA extractable Mn content was the highest at low dose of FCD (200 kg FCD ha^{-1}) over control (no application of organic manure). The application of FYM @ 200kg FYM ha^{-1} also significantly increased the DTPA extractable Mn over control, but the increase brought about by FYM was much lower as compared to FCD application possibly due to the highly decomposable nature of FCD. Reddy and Reddy (1999) also noted that DTPA extractable cationic micronutrients (Fe, Cu, Mn and Zn) were significantly increased with the integrated use of manure and fertilizers.

The main effect of Zn levels significantly influenced the DTPA extractable Mn of soil. The levels of DTPA extractable Mn was significantly lower at all Zn levels as compared to the control except at 2.5 kg Zn ha^{-1} level where it was significantly higher than the control.

The interaction effect of time of incubation and organic manure (T x M) influenced the DTPA extractable Mn content significantly. Application of FYM and especially, FCD maintained significantly higher levels of DTPA extractable Mn as compared to no application of organic manure at all time intervals however, at 5 WAI the level of DTPA extractable Mn declined significantly under FYM treatment as compared to no organic manure application but under FCD application the DTPA extractable Mn remained still significantly higher.

The interaction effect of zinc levels and organic manure application (Z x M) also influenced DTPA extractable Mn-content of soil significantly. In the absence of organic manure, application of Zn declined the level of DTPA extractable Mn significantly as compared to control (0 kg Zn ha^{-1}). In the presence of organic manure (FYM and FCD), the content of DTPA extractable Mn under different rates of Zn application either remained significantly higher or *at par* in comparison to control. Mukhopadhyay et al. (2001) studied the effect of organic manure, lime and Zn application on the availability of Mn in the acid soil under submergence. They reported an initial increase of extractable Mn content with the progress of submergence followed by a decreasing trend for the subsequent time intervals.

The interaction effect of time of incubation and zinc levels (T x Zn) had significant influence on the DTPA extractable Mn content of soil. In general, DTPA extractable Mn content of soil significantly declined with the increasing time intervals at all Zn levels however, at the highest Zn level (5 kg Zn ha^{-1}), the content of DTPA extractable Mn failed to show any decline in between 5 to 9 WAI.

The three factor interaction of time of incubation, Zn levels and organic manure (T x Zn x M) also significantly influenced DTPA extractable Mn content of soil. In general, no definite trend could be deduced from the data however, the application of FCD appeared to be more effective in maintaining higher DTPA extractable Mn content as compared to FYM at most time intervals.

CONCLUSIONS

Thus, application of Zn pre-incubated with low rates of organic manures under lowland rice culture influenced the availability of all micronutrient cations in the soil. Field experiments need to be conducted to evaluate the effect of Zn pre-incubated organic sources on the crop yields and Zn utilization efficiency by the crops.

ACKNOWLEDGEMENTS

The financial support from G.B. Pant University of Agriculture and Technology, Pantnagar, India, is gratefully acknowledged. We thank Director Research, Dean (Research) Agriculture College and Head, Department of Soil Science for providing all essential support to carry out this experiment.

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Received 28 January 2016
Accepted 18 Apeil 2016