EFFECT OF SOIL APPLICATION OF LHA ON THE NUTRIENT AVAILABILITY IN THREE DIFFERENT SOIL SERIES – AN INCUBATION STUDY.

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ABSTRACT

An incubation experiment was conducted to study the effect of soil application of Lignite humic acid (LHA) on the nutrient availability in soil. Soils collected from three major vegetable growing regions of Cuddalore district representing three soil series *viz.*, Mangadu (Mgd), Padugai (Pdg) and Vadalapakkam (Vdm) were incubated with six levels of LHA (0, 10, 20, 30, 40 and 50 mg kg^{-1}). Soil samples were drawn at 15 days intervals (0, 15, 30, 45 and 60 days after incubation) and were analysed for available N, P, K, Zn, Fe, Mn and Cu. The results of the incubation study revealed that incubation of soil with LHA increased the availability of N, P, K, Zn, Fe, Mn and Cu. Increase in the level of LHA from 0 to 40 mg kg^{-1} positively increased the both macro and micronutrients status of soil.

IndexTerms - Mangadu (Mgd), Padugai (Pdg) and Vadalapakkam (Vdm) soil series.

INTRODUCTION

Intensive cropping of land using high yielding varieties and high analysis fertilizers have led to decline in soil fertility, micronutrient deficiency and other unfavourable physical and biological conditions of soil. Thus, the soil health has been deteriorating year after year. In order to restore the soil fertility and maintain nutrient availability at an optimum level for sustaining soil health and productivity, INM becomes inevitable in Indian agriculture.

Vegetables being the heavy feeder of both macro and micronutrients, require effective INM practices to improve the productivity as well as to sustain soil health. Though the organic manures are important component of INM and supplies both macro and micronutrients to plants, soil humus content could not be improved to a desired level in a short period by the application of organic manures. Hence, inclusion of humic substances in INM become an imperative need to develop an efficient INM practice for crops as well as to improve the soil quality.

Humic substances are very important component of soil that affect physical and chemical properties and improve soil fertility. They are complex and heterogenous mixture of poly dispersed materials formed by biochemical and chemical reactions during the decay and transformation of plant and microbial remains.

It is now well established that soil application of humic substances enhanced plant growth both directly and indirectly. Physically they promote good soil structure and increased water holding capacity of the soil. Biologically they affect the activities of microorganisms. Chemically they serve as an adsorption and retention complex for inorganic plant nutrients. Nutritionally, they are source of nitrogen, phosphorus and sulphur for plants and microorganisms. Physiologically, they act as growth regulator like IAA. All these effects increases the productivity of soil.

Of course, the commercially available humic substances added to the soil do not directly contribute significant quantities of nutrients to plants in modern agriculture at the rates normally applied. However, indirect effects of these materials on soil fertility can be significant. Micronutrients especially iron, zinc and manganese may be made more available to plants in the presence of humic substances.

MATRIALS AND METHODS

DETAILS OF INCUBATION EXPERIMENT

An incubation experiment was conducted to study the effect of soil application of LHA on the release pattern of N, P, K, Zn ,Fe, Mn and Cu in soil. Three surface (0-15 cm depth) soil samples were collected at Vallampadugai, Palur and Virudhachalam which represented three different soil series *viz.*, Padugai, Vadalapakkam and Mangadu series were processed and filled in 200 g capacity polythene cups. The treatments consisted of six levels of LHA ranging from 0-50 mg kg^{-1}. Soil moisture during the incubation period was maintained at field capacity. The experiment was conducted in a completely randomized design with the following treatments. Each treatment was replicated three times.

Treatment Details

Notation used		Treatments	Soils
T_1	-	Control	S_1 - Vallampadugai (Typic Ustifluvents) S_2 - Palur (Fluvarotic Ustropept) S_3 - Virudhachalam (Typic Haplustalfs)
T_2	-	10 mg LHA kg^{-1}	
T_3	-	20 mg LHA kg^{-1}	
T_4	-	30 mg LHA kg^{-1}	
T_5	-	40 mg LHA kg^{-1}	
T_6	-	50 mg LHA kg^{-1}	

The soil samples were collected at 0, 15, 30, 45 and 60 days after incubation and analyzed for available nitrogen ($KMnO_4$ - Oxidisable), available phosphorus (Olsen-P), available potassium (NH_4OAc-extractable) and available Zn, Fe, Mn and Cu (DTPA Extractable).

RESULTS AND DISCUSSION

The results of the incubation experiment carried out to study the effect of humic acid on the release pattern of available nitrogen, phosphorus, potassium and DTPA extractable Zn, Fe, Mn and Cu in the three experimental soil samples were furnished here under.

Available nitrogen (Table 1)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 40 mg kg^{-1} consistently increased the available nitrogen content in all the three soils and it ranged from 123.1 to 157.1 mg kg^{-1} in S_1, 111.8 to 129.6 mg kg^{-1} in S_2 and 104.4 to 119.7 mg kg^{-1} in S_3, but a decrease in the available nitrogen status was recorded at 50 mg LHA kg^{-1}.

At all levels of LHA, increase in the days of incubation from 0 to 45 DAI increased the available nitrogen content from 122.0 to 168.5 mg kg^{-1} in S_1, 107.60 to 138.50 mg kg^{-1} in S_2 and 98.7 to 122.9 mg kg^{-1} in S_3. Further increase in the period of incubation (60 DAS) slightly decrease the available N content. Among the three soils, S_1 recorded the highest available nitrogen at all levels of LHA as compared to other two soils. The lowest available nitrogen content was recorded in S_3.

A significant interaction effect due to LHA and DAI on available N content was noticed. The maximum available nitrogen content of 184.2, 145.1and 135.2 mg kg^{-1} in S_1, S_2 and S_3 respectively was noticed on 45 DAI. The lowest available nitrogen content of 98.7 mg kg^{-1} in S_3 soil, 119.5 mg kg^{-1} in S_1 soil and 107.1 mg kg^{-1} in S_2 was recorded in control. This might be due to the accelerated rate of mineralization of soil organic matter due to increased microbial activity (Deepa and Govindarajan, 2002). The addition of humic acid might have an added effect on the rate of mineralization and release of N. The decrease in the available N at LHA levels higher than 40 mg kg^{-1} might be due to reduced microbial activity in the presence of high content of phenolic OH present in LHA (Sathiyabama *et al*., 2005b).

Available phosphorus (Table 2)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 50 mg kg^{-1} consistently increased the available phosphorus content in all the three soils and it ranged from 4.6 to 7.6 mg kg^{-1} in S_1, 4.3 to 5.6 mg kg^{-1} in S_2 and 4.7 to 6.7 mg kg^{-1} in S_3. In all the three types of soils, increase in the days of incubation from 0 to 60^{th} DAI increased the available phosphorus content at all LHA levels. Irrespective of the level of LHA, increase in the days of incubation. LHA increased the available P content and it ranged from 4.5 to 6.7 mg kg^{-1} inS_1, 4.3 to5.4 mgkg^{-1} inS_2 and4.7to 6.0 mg kg^{-1} in S_3. Among the three soils, S_1 soil recorded the highest available phosphorus content (6.0 mg kg^{-1}) as compared to other two soils. The lowest available phosphorus content was recorded in S_2.

Interaction effect due to LHA and DAI was significant. The highest available phosphorus content of 8.8 mg kg^{-1} was noticed on 60 DAI in S_1 applied with 50 mg LHA kg^{-1}. In S_2 and S_3, the highest available phosphorus content of 6.3 and 7.2 mg kg^{-1} in 60 DAI was recorded in the treatment which received 50 mg LHA kg^{-1}. The lowest available phosphorus content at 4.5 mg kg^{-1} in S_1, 4.3 mg kg^{-1} in S_2 and 4.7 mg kg^{-1} in S_3 soil was recorded in control.

This could be ascribed to the fact that humic acid being anionic might have enhanced P release by competing for exchange sites. Further the humic acid might have formed a protective coating over sesquioxides and reduced the fixation of P thereby increased the P availability in soil (Khan *et al*., 1997).

Available potassium (Table 3)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 50 mg kg^{-1} consistently increased the available potassium content in all the three soils and it ranged from 92.9 to 127.3 mg kg^{-1} in S_1, 68.8 to 85.0 mg kg^{-1} in S_2 and 68.2 to 88.9 mg kg^{-1} in S_3. Increase in the days of incubation from 0 to 60 DAI increased the available potassium content in all levels of LHA. Among the three soils, S_1 recorded the highest available potassium (119.0 mg kg^{-1}) as compared to S_2 (74.7 mg kg^{-1}) and S_3 (81.3 mg kg^{-1}).

Interaction effect due to LHA and DAI are available K was significant. The maximum available potassium content of 140.1 mg kg^{-1} was noticed on 60 DAI in S_1 which received 50 mg LHA kg^{-1}. In S_2 and S_3, the maximum available potassium content of 94.0 mg kg^{-1} and 99.2 mg kg^{-1} on 60 DAI was recorded in the treatment which received 50 mg LHA kg^{-1}.

The lowest available potassium content at 86.5 mg kg^{-1} in S_1, 66.0 mg kg^{-1} in S_2 and 63.5 mg kg^{-1} in S_3 was recorded in control. The probable exchange between humate ions and exchangeable K might be a reason for the increase in K availability (Dusan *et al*., 1999). A steady increase in the available K from 15th to 60th day might be due to solubilizing effect caused by humic acid coupled with the release from exchangeable sites by other cations (Khan *et al*., 1997; Sathiyabama *et al*., 2003).

Available zinc (Table 4)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 40 mg kg^{-1} consistently increased the available zinc content in all the three soils and it ranged from2.73to5.49 mg kg^{-1}in S_1, 1.81 to 3.94 mg kg^{-1} in S_2 and 0.60 to 2.37 mg kg^{-1} in S_3, but a decrease in the available zinc status was recorded at 50 mg kg^{-1} of LHA.

Irrespective level of LHA, increase in the days of incubation from 0 to 45 DAI increased the available zinc content and ranged from 3.19 to 4.47 mg kg^{-1} in S_1, 2.56 to 3.63 mg kg^{-1} in S_2 and 0.68 to 2.28 mg kg^{-1} in S_3 in all the three soils tried. Among the three soils, S_1 recorded the highest available zinc content as compared to other two soils. The lowest available zinc content was recorded in S_3.

Interaction effect due to LHA and DAI was significant. The maximum available zinc content of 4.12 mg kg^{-1} was noticed on 45 DAI is S_2 which received LHA @ 40 mg kg^{-1}. In S_1 and S_3, the maximum available zinc content of 6.24 mg kg^{-1} and 3.20 mg kg^{-1} was recorded on 45 DAI in the treatment receiving LHA @ 40 mg LHA kg^{-1}. The lowest available zinc content of 2.64 mg kg^{-1} in S_1, 0.92 mg kg^{-1} in S_2 and 0.57 mg kg^{-1} in S_3 was recorded in control. Among the three soils, S_1 (Typic Ustifluvents) registered the highest Zn and Mn. Higher available Fe content was observed in S_3 (Typic Haplustalf), however maximum available Cu content was observed in S_2 (Fluvarotic ustropept). Application of humic acid to soil increased the micronutrient availability in two ways. First humic acids might have improved the dissolution of minerals and brought about their disintegration, thereby releasing nutrients from a molecular state to an adsorbed state (ionic), which would have become more readily available to higher plants. The second mechanism for increasing the availability of micronutrients would be through the formation of stable organo mineral complexes of ions such as Fe^{2+}, Cu^{2+}, Zn^{2+} and Mn^{2+} with humate ligands. This was supported by Sathiyabama *et al*. (2005b).

Available iron (Table 5)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 50 mg kg^{-1} consistently increased the available iron content in all the three soils and it ranged from15.50to23.98mgkg^{-1}inS_1,12.79to 18.42 mg kg^{-1} in S_2 and 32.52 to 53.48 mg kg^{-1} in S_3.

Increase in the days of incubation from 0 to 45 DAI increased the available iron content, at all levels of LHA but a decrease in the available iron status was recorded at 60 DAI. This trend was commonly observed in all the three experimental soils. Among the three soils, S_3 recorded the highest available iron as compared to S_1 and S_2. The lowest available iron content was recorded in S_2.

The maximum available iron content of 98.0 mg kg^{-1} was noticed on 45 DAI in S_3 applied with 50 mg LHA kg^{-1}. In S_1 and S_2, the maximum available iron content of 38.47 mg kg^{-1} and 22.59 mg kg^{-1} on 45 DAI was recorded in the treatment which received LHA @ 50 mg kg^{-1}. The lowest available iron content of 10.13 mg kg^{-1} in S_1, 8.46 mg kg^{-1} in S_2 and 17.53 in S_3 was recorded in control.

Available manganese (Table 6)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 50 mg kg^{-1} consistently increase the available manganese content in all the three soils and it ranged from 29.02 to 52.14 mg kg^{-1} in S_1, 22.32 to 36.17 mg kg^{-1} in S_2 and 11.79 to 16.86 mg kg^{-1} in S_3.

Regardless of the level of LHA, increase in the days of incubation from 0 to 45 DAI increased the available manganese content. Among the three soils, S_1 recorded the highest available manganese (40.62 mg kg^{-1}) as compared to S_2 (28.79 mg kg^{-1}) and S_3 (14.03 mg kg^{-1}).

A positive interaction effect due to LHA and DAI on available Mn was observed. The maximum available manganese content of 58.06 mg kg^{-1} was noticed on 45 DAI in S_1 which received LHA @ 50 mg kg^{-1}. In S_2 and S_3, the maximum available manganese content of 47.99 mg kg^{-1} and 19.94 mg kg^{-1} on 45 DAI was recorded in treatment applied with 50 mg LHA kg^{-1}. The lowest available manganese content of 6.47 mg kg^{-1} in S_3, 16.02 mg kg^{-1} in S_2 and 25.11 mg kg^{-1} in S_1 was recorded in control.

Available copper (Table 7)

Irrespective of the days of incubation, application of increasing levels of LHA from 0 to 40 mg kg^{-1} consistently increase the available copper content in all the three soils and it ranged from0.61to0.78mgkg^{-1}inS_1,0.68to 0.91 mg kg^{-1} in S_2 and 0.61 to 0.71 mg kg^{-1} in S_3, but a decrease in the available copper status was recorded at 50 mg kg^{-1}.

In all the three soils, irrespective of level of LHA, increase in the days of incubation from 0 to 30 DAI increased the available copper content. Among the three soils, S_2 recorded the highest available copper content as compared to other two soils. The lowest available copper content was recorded in S_3.

The interaction effect due to LHA and DAI on available Cu was significant. The maximum available copper content of 0.94 mg kg^{-1} was noticed on 30 DAI in S_2 which received LHA @ 40 mg kg^{-1}. In S_1 and S_3, the maximum available copper content of 0.86 mg kg^{-1} and 0.82mgkg^{-1}on 30 DAI was recorded in treatment applied with LHA @ 40 mg kg^{-1}. The lowest available copper content of 0.56 mg kg^{-1} in S_1, 0.64 mg kg^{-1} in S_2 and 0.54 mg kg^{-1} in S_3 was recorded in control. Application of humic acid to soil increased the micronutrient First humic acids might have improved the dissolution of minerals and brought about their disintegration, thereby releasing nutrients from a molecular state to an adsorbed state (ionic), which would have become more readily available to higher plants. The second mechanism for increasing the availability of micronutrients would be through the formation of stable organo mineral complexes of ions such as Fe^{2+}, Cu^{2+}, Zn^{2+} and Mn^{2+} with humate ligands. This was supported by Sathiyabama *et al*. (2005b).

SUMMARY AND CONCLUSION

Soils collected from three major vegetable growing regions of Cuddalore district of Tamil Nadu, India were incubated with six levels of LHA (0, 10, 20, 30, 40 and 50 mg kg^{-1}). Soil samples were drawn at 15 days intervals and analysed for available N, P, K, Zn, Mn, Fe and Cu. The results of the study showed that increase in the level of LHA from 0-40 mg kg^{-1} consistently increased the availability of N and Zn in soil whereas the availability of P, K, Fe and Mn increased with increased levels of LHA even up to 50 mg LHA kg^{-1}.

Irrespective of the level of LHA, increase in the days of incubation increased the availa[illegible] NPK as well as Zn, Mn, Cu and Fe. The highest P and K content on 60 DAI, Fe and Mn content on 45 DAI and Cu conte[illegible] DAI in the treatment which received LHA @ 40 mg kg^{-1}.Incubation of soil with LHA increased the availability of N, P, K, Zn, Fe, Mn and Cu.

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Table 1. Effect of LHA on the release pattern of available nitrogen ($KMnO_4$ extractable) in soil (mg kg^{-1})

DAI / Levels of LHA (mg kg^{-1})	S_1						S_2						S_3					
	DAI																	
	0^{th}	15^{th}	30^{th}	45^{th}	60^{th}	Mean	0^{th}	15^{th}	30^{th}	45^{th}	60^{th}	Mean	0^{th}	15^{th}	30^{th}	45^{th}	60^{th}	Mean
0	119.5	122.5	124.0	126.0	123.5	123.1	107.1	108.2	110.4	119.1	114.2	111.8	98.7	100.0	104.0	110.0	109.0	104.4
10	122.0	125.6	134.6	174.1	168.3	144.9	107.0	110.1	121.5	141.0	133.9	122.7	98.7	107.4	115.0	127.7	126.2	115.0
20	122.0	132.0	137.8	178.4	175.8	149.4	107.0	113.1	122.4	141.6	138.4	124.5	98.7	108.4	166.7	128.3	126.7	115.7
30	122.0	137.8	149.3	182.1	180.0	154.2	107.0	117.2	125.9	142.6	139.0	126.3	98.7	108.4	115.7	122.4	120.6	113.2
40	122.1	139.1	157.4	184.2	182.6	157.1	107.0	119.3	132.4	145.1	141.1	129.6	98.7	111.6	123.2	135.2	130.2	119.7
50	122.0	131.4	140.3	166.2	159.6	144.0	107.0	118.1	122.5	141.5	135.0	124.8	98.7	106.2	112.6	114.0	111.6	108.6
Mean	122.0	131.4	140.7	168.5	164.9	145.4	107.0	114.3	122.5	138.5	133.6	123.2	98.7	107.0	114.5	122.9	120.7	112.8

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	0.92	1.80	A x B	2.06	4.04
B – Soil	1.19	2.33	A x C	2.26	4.43
C – DAI	1.30	2.55	B x C	2.91	5.72
			A x B x C	5.05	9.90

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Table 2. Effect of LHA on the release pattern of available Phosphorus (Olsen-P) in soil (mg kg^{-1})

DAI / Levels of LHA (mg kg^{-1})	S_1						S_2						S_3					
	DAI																	
	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean
0	4.5	4.5	4.6	4.7	4.7	4.6	4.3	4.3	4.3	4.4	4.4	4.3	4.7	4.7	4.7	4.8	4.48	4.7
10	4.5	4.8	4.9	5.3	5.4	5.0	4.3	4.4	4.6	4.8	4.9	4.6	4.7	4.8	5.0	5.1	5.2	5.0
20	4.5	4.9	5.4	5.8	6.1	5.3	4.3	4.8	4.9	5.0	5.2	4.8	4.7	4.8	5.2	5.5	5.8	5.2
30	4.5	6.0	6.4	6.8	7.0	6.1	4.3	5.0	5.2	5.4	5.6	5.1	4.7	4.9	5.4	5.8	6.1	5.4
40	4.5	7.2	7.5	7.9	8.4	7.1	4.3	5.4	5.5	5.6	5.8	5.3	4.7	5.0	6.2	6.4	6.8	5.8
50	4.5	8.0	8.2	8.6	8.8	7.6	4.3	5.6	5.8	6.0	6.3	5.6	4.7	5.2	6.4	6.9	7.2	6.7
Mean	4.5	5.9	6.2	6.5	6.7	6.0	4.3	4.9	5.1	5.2	5.4	5.0	4.7	4.9	5.5	5.8	6.0	5.4

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	0.04	0.08	A x B	0.03	0.06
B – Soil	0.07	0.14	A x C	0.01	0.10
C – DAI	0.13	0.26	B x C	0.05	0.10
			A x B x C	0.07	0.14

Table 3. Effect of LHA on the release pattern of available Potassium (NH_3OAc extractable) in soil (mg kg^{-1})

DAI / Levels of LHA (mg kg^{-1})	S1						S2						S3					
	DAI																	
	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean
0	86.5	88.4	92.7	96.0	101.0	92.9	66.0	67.6	69.2	70.0	71.4	68.8	63.5	65.0	69.0	73.4	70.1	68.2
10	86.5	130.0	130.0	130.5	131.0	121.6	66.1	67.5	69.0	70.5	72.6	69.1	63.5	80.0	81.2	82.7	82.1	77.9
20	86.5	130.4	131.0	131.6	132.1	122.3	66.4	70.0	71.0	73.4	76.0	71.3	63.5	85.0	85.5	87.1	86.4	81.4
30	86.5	132.9	133.4	133.6	134.1	124.1	66.5	74.0	76.0	79.4	82.1	75.6	63.5	88.3	88.9	92.4	90.0	84.6
40	86.5	134.0	135.0	137.1	138.0	126.1	66.7	77.1	79.2	83.3	85.1	78.3	63.5	90.0	92.0	94.1	93.4	86.6
50	86.5	135.2	136.4	138.2	140.1	127.3	66.8	87.1	88.0	89.0	94.0	85.0	63.5	90.0	95.0	99.2	97.1	88.9
Mean	86.5	125.1	126.4	127.8	129.4	119.0	66.4	73.9	75.4	77.6	80.2	74.7	63.5	83.0	85.3	88.0	86.6	81.3

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	1.16	2.26	A x B	2.31	4.52
B – Soil	1.33	2.61	A x C	2.82	5.54
C – DAI	1.63	3.19	B x C	3.26	6.39
			A x B x C	5.65	11.08

Table 4. Effect of LHA on the release pattern of available Zinc (DTPA extractable) in soil (mg kg^{-1})

DAI / Levels of LHA (mg kg^{-1})	S_1						S_2						S_3					
	DAI																	
	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean
0	2.64	2.66	2.68	3.00	2.67	2.73	0.92	0.98	1.89	2.64	2.60	1.81	0.57	0.58	0.59	0.69	0.58	0.60
10	2.65	3.80	3.84	3.86	3.82	3.59	2.08	2.60	2.82	3.24	3.02	2.75	0.62	1.00	0.88	0.98	0.80	0.86
20	3.01	3.96	3.98	4.24	4.02	3.84	2.89	3.28	3.30	3.68	3.53	3.34	0.63	1.02	2.04	2.80	2.00	1.70
30	3.28	4.35	4.38	4.46	4.40	4.17	3.02	3.56	4.02	4.06	4.00	3.73	0.73	2.40	2.60	3.06	2.20	2.20
40	4.26	5.26	5.62	6.24	6.06	5.49	3.42	4.06	4.08	4.12	4.02	3.94	0.84	2.60	2.80	3.20	2.40	2.37
50	3.27	4.20	4.38	5.02	4.96	4.37	3.00	3.52	4.01	4.03	4.00	3.71	0.66	2.38	2.42	2.64	2.28	2.08
Mean	3.19	4.04	4.15	4.47	4.32	4.03	2.56	3.00	3.35	3.63	3.53	3.21	0.68	1.67	1.89	2.23	1.71	1.64

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	0.2160	0.4234	A x B	0.4831	0.9468
B – Soil	0.2789	0.5467	A x C	0.5292	1.0372
C – DAI	0.3055	0.5988	B x C	0.6832	1.3390
			A x B x C	1.1833	2.3193

Table 5. Effect of LHA on the release pattern of available Iron (DTPA extractable) in soil (mg kg^{-1})

DAI / Levels of LHA (mg kg^{-1})	S$_1$						S$_2$						S$_3$					
	DAI																	
	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean
0	10.13	13.56	13.63	21.00	19.20	15.50	8.46	13.11	13.88	14.59	13.89	12.79	17.53	17.66	31.78	53.88	41.73	32.52
10	10.69	13.82	16.18	23.52	22.10	17.26	9.67	14.29	14.54	18.02	15.34	14.37	17.64	18.41	35.95	73.97	55.03	40.20
20	11.12	14.18	18.75	27.98	25.27	19.46	9.92	14.65	15.11	18.02	17.79	15.10	17.68	18.57	39.82	75.40	58.62	42.02
30	11.12	16.84	18.82	28.12	26.98	20.38	10.76	15.89	17.05	20.87	18.04	16.52	17.69	20.78	44.90	78.24	62.40	44.80
40	12.69	17.01	19.39	30.85	28.77	21.74	11.10	15.94	18.71	21.74	21.10	17.72	18.00	28.01	46.78	97.30	62.67	50.55
50	13.10	17.24	21.60	38.47	29.50	23.98	11.40	16.71	19.67	22.59	21.75	18.42	18.00	29.20	51.25	98.00	70.93	53.48
Mean	11.48	15.44	18.06	28.32	25.30	19.72	10.22	15.10	16.50	19.31	18.00	15.82	17.76	22.11	41.75	79.47	58.56	43.93

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	0.8627	1.6910	A x B	1.9291	3.7811
B – Soil	1.1138	2.1830	A x C	2.1133	4.1420
C – DAI	1.2201	2.3914	B x C	2.7282	5.3473
			A x B x C	4.7254	9.2618

Table 6. Effect of LHA on the release pattern of available Manganese (DTPA extractable) in soil (mg kg^{-1})

Levels of LHA (mg kg^{-1}) \ DAI	S_1						S_2						S_3					
	DAI																	
	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean
0	25.11	25.51	31.16	38.46	24.84	29.02	16.02	18.25	25.37	34.06	22.92	22.32	6.47	6.82	14.40	16.28	14.99	11.79
10	25.67	37.79	38.80	39.40	25.39	33.41	16.54	20.64	29.69	34.27	27.83	25.79	6.52	6.85	15.47	17.04	14.99	12.17
20	33.79	39.30	40.02	40.66	30.65	36.88	16.55	21.67	31.12	35.17	28.02	26.51	7.18	9.61	15.48	17.28	16.77	13.26
30	36.33	47.68	48.23	48.89	36.42	43.51	17.83	23.38	36.61	37.17	31.32	29.26	9.73	10.64	17.30	18.20	17.19	14.61
40	36.78	55.11	56.20	56.80	38.44	48.67	17.97	25.54	41.49	41.69	31.79	31.70	9.79	12.26	18.60	18.62	18.20	15.49
50	42.76	57.70	58.02	58.06	44.15	52.14	18.36	31.14	43.80	47.99	39.58	36.17	11.09	14.85	19.36	19.94	19.04	16.86
Mean	33.41	43.85	45.41	47.05	33.32	40.62	17.21	23.44	34.68	38.39	30.24	28.79	8.46	10.17	16.77	17.89	16.86	14.03

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	0.7364	1.4434	A x B	1.6467	3.2276
B – Soil	0.9507	1.8635	A x C	1.8039	3.5357
C – DAI	1.0415	2.0413	B x C	2.3288	4.5645
			A x B x C	4.0337	7.9060

Table 7. Effect of LHA on the release pattern of available Copper (DTPA extractable) in soil (mg kg^{-1})

Soil / Levels of LHA (mg kg^{-1})	S_1						S_2						S_3					
	DAI																	
	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean	0th	15th	30th	45th	60th	Mean
0	0.56	0.57	0.68	0.62	0.62	0.61	0.64	0.68	0.72	0.70	0.68	0.68	0.54	0.61	0.71	0.69	0.48	0.61
10	0.57	0.63	0.69	0.66	0.64	0.64	0.70	0.76	0.78	0.74	0.72	0.74	0.55	0.62	0.74	0.70	0.65	0.65
20	0.57	0.64	0.70	0.68	0.64	0.65	0.78	0.80	0.84	0.82	0.80	0.81	0.56	0.64	0.75	0.72	0.68	0.67
30	0.60	0.68	0.72	0.70	0.70	0.68	0.82	0.84	0.86	0.84	0.82	0.84	0.56	0.66	0.76	0.72	0.70	0.68
40	0.67	0.72	0.86	0.84	0.80	0.78	0.89	0.92	0.94	0.90	0.89	0.91	0.58	0.68	0.82	0.73	0.72	0.71
50	0.63	0.64	0.72	0.68	0.70	0.67	0.86	0.88	0.90	0.88	0.86	0.88	0.55	0.64	0.75	0.69	0.68	0.66
Mean	0.60	0.65	0.73	0.70	0.68	0.67	0.78	0.81	0.84	0.81	0.80	0.81	0.56	0.64	0.76	0.71	0.65	0.66

	SEd	CD (p=0.05)		SEd	CD (p=0.05)
A - LHA	0.0250	0.0494	A x B	0.1105	0.1454
B – Soil	0.0325	0.0638	A x C	0.1210	0.1593
C – DAI	0.0356	0.0699	B x C	0.1562	0.2056
			A x B x C	0.2706	0.3562