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RESEARCH ARTICLE

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Assessment of Acidic Soil Nutrient Stoichiometry on Molybdenum Fertilization for Sustainable Crop Production

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ABSTRACT

Background: Molybdenum (Mo), an essential micronutrient, is known to have a profound influence on various biochemical and physiological processes in plants. A variety of factors, including soil pH, organic matter content and the abundance of particular minerals that interact with nutrient dynamics, affect the availability of essential nutrients in the soil. Acidic soil conditions frequently cause lower nutrient availability as a result of influencing factors like increased manganese and aluminium toxicity as well as lesser microbial activity. Soil acidification can impact agricultural productivity. For the creation of efficient and long-lasting soil management techniques that can ease nutrient constraints and boost agricultural productivity, it is essential to comprehend the impact of molybdenum on the dynamics of soil macronutrients and micronutrients in acid soils.

Methods: A 60 days incubation experiment was carried out under laboratory conditions to study the effect of molybdenum fertilization on the release pattern of molybdenum and other nutrients from the soil. Soil samples were filled in jars and treatments were imposed. Samples were collected at 15, 30, 45 and 60 days of incubation, dried and processed for available nitrogen, phosphorus and DTPA extractable micronutrients.

Result: Molybdenum addition showed a significant influence on the release of various nutrients present in the soil. It was also observed that molybdenum has a synergistic effect on available nitrogen and phosphorus, while it exhibited antagonism towards DTPA extractable micronutrients, namely Zn, Fe, Mn and Cu. Molybdenum fertilization holds great promise for enhancing the macronutrients' availability and reducing the toxicity of micronutrients in acid soils. It will be helpful for sustainable agricultural production under acidic soil.

Key words: Acidic soil, Incubation experiment, Macro and micronutrients, Molybdenum.

INTRODUCTION

Acidic soils pose significant challenges to agricultural productivity, primarily due to their adverse effects on nutrient availability and uptake. Acidic soils are characterized by low pH levels resulting from the accumulation of hydrogen ions and the leaching of essential nutrients (Msimbira and Smith, 2020). This acidic environment impairs nutrient availability and uptake, leading to nutrient deficiencies, stunted growth and reduced crop yields (Marschner, 2011). Acidic soils often exhibit reduced availability and potential deficiencies of major plant nutrients, including Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Calcium (Ca) and Magnesium (Mg). The trace element molybdenum (Mo) may also become limited in acidic soils (Bolan *et al*., 2023). The availability of Mo for plant growth is strongly depends on the soil pH, the concentration of adsorbing oxides (*e.g*., Fe oxides), the extent of water drainage and organic compounds found in the soil colloids (Kaiser *et al*., 2005). Mo, a trace element essential for plant growth, plays a crucial role in plants' various physiological and metabolic processes. Mo fertilizer application has shown promise in influencing nutrient dynamics and improving nutrient availability in acid soils. Understanding the effects of molybdenum fertilization on nutrient availability in acid soils is essential for optimizing fertilizer management practices and improving agricultural sustainability in acid-prone environments. The interaction of Mo with macro and micronutrients in acid soils plays a pivotal role in nutrient availability and uptake by plants.

Recent research has discovered supporting evidence indicating the involvement of Mo in N cycling. Mo, which is a constituent of nitrogenase, has the potential to form complex with organic matter present in soil (Barron *et al*.,

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2009) and potentially impact the transformation and movement of N within the soil (Hu *et al*., 2002). Soil application of Mo leads to increased availability of P, crude protein and other crucial macro-elements, consequently resulting in a positive impact on P availability (Nie *et al*., 2015). Moreover, the influence of molybdenum on the availability of essential micronutrients, such as zinc (Zn), copper (Cu) and iron (Fe), in acid soils has also gained attention. In numerous crops, Cu and Mo exhibit antagonistic effects. Mo exacerbates Fe deficiency by forming a precipitate of Fe molybdate in the roots (Kumar *et al*., 2016). These findings indicate that molybdenum supplementation may contribute to the sustainable management of acid soils by improving the availability and utilization of essential micronutrients.

Understanding the influence of Mo on the dynamics of soil macronutrients and micronutrients in acidic soils is vital for developing effective and sustainable soil management practices that can alleviate nutrient limitations and promote agricultural productivity. It may be helpful for sustainable crop production under acidic soil. Therefore, this present study was carried out to study the effect of molybdenum fertilization on nutrient availability in the acid soils of Nilgiris.

MATERIALS AND METHODS

Experiment details and treatments

A 60 days incubation experiment was carried out at Ph. D laboratory, Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore (11°01′54.34″N 76°93′45.39″E), India, during the year 2022 to study the effect of Mo fertilization on the release pattern of Mo and other nutrients from the soil. Soil samples were collected from the Wood House Farm of Horticultural Research Station (HRS), TNAU, Ooty (11°42′43.61″N 76°72′39.5″E), Nilgiri district of Tamil Nadu, India. The collected soil samples were air-dried and filled in plastic jars. 100 g of soil was filled in each jar (8 cm × 5 cm). Treatments were imposed using two molybdenum fertilizers, ammonium molybdate (S_1) and sodium molybdate (S_2), with five levels *viz*., 0 (L_0), 0.1 (L_1), 0.2 (L_2), 0.3 (L_3) and 0.4 (L_4) mg Mo per kg of soil with three replications. The experiment was carried out in a Factorial Completely Randomized Block Design (FCRD). The content in each jar was thoroughly mixed with the help of a glass rod. Moisture content was adjusted to field capacity and each jars' initial weight was noted. The jars were weighed every three days and the difference from the initial weight was settled by the addition of deionised water. The jars were closed properly and kept at room temperature for 60 days. The physico-chemical properties of initial soils was given in Table 1. The soil under the study was acidic in nature (pH 4.92), non-saline (EC 0.72 dS m^{-1}), had high organic carbon content (37.1 g kg^{-1}), medium in available nitrogen (286 kg ha^{-1}) and phosphorus (34.40 kg ha^{-1}) and low in available potassium (193 kg ha^{-1}).

Sample collection and analyses

Samples were collected at 15, 30, 45 and 60 days of incubation following the destructive sampling method. Samples were dried and processed and kept for chemical analysis. The processed samples were analysed for available N (Asija and Subbiah, 1956), available P (Bray and Kurtz, 1945) and DTPA extractable micronutrients (Lindsay and Norwell, 1969).

Statistical analysis

The statistical analyses were conducted using RStudio (RStudio Team, 2016). Tukey's HSD test, for all lettered differences, was performed using the HSD.test command available in the agricolae package (de Mendiburu, 2016).

RESULTS AND DISCUSSION

Available nitrogen

The application of different levels of Mo significantly influenced the release of available N throughout the period of incubation study (Table 2). The available N showed a consistent increase with the increased levels of Mo up to 45 days of incubation then a decreasing trend was observed in both S_1 and S_2. Compared with the ammonium molybdate, the application of sodium molybdate at a higher dose exhibited a more significant effect on available N. Application of ammonium molybdate resulted in the improved release of available N from 285 to 294 kg N ha^{-1}, while in the case of sodium molybdate it marked a transformation from 287 to 296 kg N ha^{-1}. S_1 and S_2 significantly differed from each other. The mean values for different levels showed a gradual increase from L_0 to L_4, which indicated a positive relationship between available N and different levels of Mo. Similar to the results for S_1 and S_2, the mean values for L were consistently higher than those for S_2 than S_1 at each incubation interval. Among the different levels of Mo, the greatest release of N, *i.e*., 291 and 293, 293 and 295, 294 and 296, 289 and 292 kg ha^{-1}, respectively, was observed with the application of Mo @ 0.4 mg kg^{-1} soil (L_4) throughout the incubation period for both sources. The differences between the means of L_0, L_1, L_2, L_3 and L_4 were statistically

Table 1: Initial physico- chemical properties of the experimental soil.

Properties	Values
pH (1:2.5)	4.92
EC (dS m^{-1})	0.72
Organic carbon (g kg^{-1})	37.1
CEC (cmol (p^+) kg^{-1})	21.45
Available nitrogen (kg ha^{-1})	286
Available phosphorus (kg ha^{-1})	34.40
Available potassium (kg ha^{-1})	193
DTPA extractable zinc (mg kg^{-1})	1.39
DTPA extractable Iron (mg kg^{-1})	56.11
DTPA extractable manganese (mg kg^{-1})	2.89
DTPA extractable copper (mg kg^{-1})	1.98

significant, which showed that the different levels of Mo fertilizer had a significant impact on the available N at varying incubation period. Application of sodium molybdate @ 0.4 mg kg^{-1} soil marked the maximum N release (296 kg ha^{-1}) at 45 DAI (days after incubation). The results also indicated that the interaction between variables S and L (S*L) had a significant impact on the available N release in the soil at each incubation interval. The differences between the means of S*L were significant at all levels, indicating that the combinations of variables S and L had a significant impact on the available N throughout the incubation period.

Mo is an essential micronutrient for N metabolism in plants and microorganisms. It plays a crucial role in the activity of nitrogenase, an enzyme responsible for biological nitrogen fixation. Nitrogenase converts atmospheric nitrogen (N_2) into ammonium (NH_4^+), which is an essential form of nitrogen for plants. Additionally, Mo is also involved in the activity of nitrate reductase (Hu *et al*., 2002), an enzyme responsible for the conversion of nitrate (NO_3^-) into nitrite (NO_2^-) and further into ammonium. By stimulating the activities of nitrogenase and nitrate reductase enzymes, Mo enhances the fixation of N in the soil. This explains the observed increase in available N in the soil with the application of Mo. Deo and Kothari (2002) and Wen *et al*. (2018) reported similar findings, suggesting that the application of molybdenum leads to enhanced nitrogen fixation in the soil.

Available phosphorus

The soil available P was significantly influenced by molybdenum sources and levels at each study interval (Table 3). The soil available P was determined at every 15 days interval and it was observed that the release rate of available P increased with increasing levels of Mo for both sources. It was also observed that the release rate of available P increased up to 45 days after incubation and then declined in both sources. When compared with the ammonium molybdate, sodium molybdate has a greater available P release. The increase of mean soil available P ranged from 37.05 to 37.45 kg P ha^{-1} with the application of sodium molybdate. With the application of ammonium molybdate, the average soil available P increased from 36.02

Table 2: Impact of molybdenum fertilization on the available nitrogen (kg ha^{-1}) content in the soil.

Mo levels (mg kg^{-1})	15 DAI			30 DAI			45 DAI			60 DAI		
	Sources			Sources			Sources			Sources		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
L_0- 0	285^{g}	287^{e}	286	286^{g}	288^{e}	287	286^{f}	288^{e}	287	285^{f}	287^{e}	286
L_1- 0.1	286^{f}	288^{d}	287	287^{f}	289^{d}	288	288^{e}	290^{cd}	289	285^{f}	288^{d}	286.5
L_2- 0.2	287^{e}	289^{c}	288	288^{e}	290^{c}	289	289^{de}	291^{c}	290	287^{e}	289^{c}	288
L_3- 0.3	288^{d}	291^{b}	289.5	290^{c}	294^{b}	292	291^{c}	295^{ab}	293	288^{d}	290^{b}	289
L_4- 0.4	291^{b}	293^{a}	292	293^{b}	295^{a}	294	294^{b}	296^{a}	295	289^{c}	292^{a}	290.5
Mean	287	290		289	291		290	292		287	289	
Variables	SE (d)		CD (p=0.05)	SE (d)		CD (p=0.05)	SE (d)		CD (p=0.05)	SE (d)		CD (p=0.05)
S	0.14		0.30	0.14		0.30	0.21		0.47	0.10		0.22
L	0.21		0.48	0.22		0.48	0.33		0.74	0.16		0.35
S*L	0.30		0.68	0.30		0.68	0.47		1.05	0.22		0.49

S_1: Ammonium molybdate; S_2: Sodium molybdate. Treatments with same letters are not significantly different ($p<0.05$).

Table 3: Impact of molybdenum fertilization on the available phosphorus (kg ha^{-1}) content in the soil.

Mo levels (mg kg^{-1})	15 DAI			30 DAI			45 DAI			60 DAI		
	Sources			Sources			Sources			Sources		
	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean	S_1	S_2	Mean
L_0- 0	34.23^{f}	34.56^{ef}	34.40	34.56^{e}	34.71^{e}	34.64	34.78^{e}	34.95^{e}	34.86	34.74^{c}	34.91^{c}	34.83
L_1- 0.1	34.91^{ef}	35.25^{de}	35.43	35.25^{de}	35.40^{de}	35.33	35.48^{de}	35.99^{de}	35.74	35.43^{bc}	35.78^{bc}	35.61
L_2- 0.2	35.09^{e}	35.94^{d}	36.80	35.94^{d}	35.92^{d}	35.93	36.00^{de}	35.92^{cd}	36.04	35.78^{bc}	36.31^{bc}	35.96
L_3- 0.3	37.31^{c}	39.05^{b}	38.18	37.32^{c}	39.22^{b}	38.27	37.00^{c}	39.49^{b}	38.14	36.52^{b}	39.27^{a}	38.01
L_4- 0.4	38.54^{b}	40.44^{a}	41.80	39.05^{b}	40.61^{a}	39.83	40.90^{b}	40.89^{a}	40.90	39.26^{a}	40.84^{a}	40.05
Mean	36.02	37.05		36.43	37.17		36.73	37.45		36.44	37.42	
Variables	SE (d)		CD (p=0.05)	SE (d)		CD (p=0.05)	SE (d)		CD (p=0.05)	SE (d)		CD (p=0.05)
S	0.14		0.32	0.22		0.48	0.30		0.66	0.21		0.47
L	0.23		0.51	0.34		0.34	0.47		1.04	0.34		0.75
S*L	0.32		0.72	0.48		1.08	0.66		1.47	0.47		1.06

S_1: Ammonium molybdate; S_2: Sodium molybdate. Treatments with same letters are not significantly different ($p<0.05$).

to 36.73 kg P ha^{-1}. Release of soil available P increased with the increased levels of Mo. Among the different levels of Mo, the greatest release was observed with the application of Mo @ 0.4 mg kg^{-1} soil (L_4) throughout the incubation period with both sources. Application of ammonium molybdate @ 0.4 mg Mo g^{-1} soil (L_4) recorded the highest available P release with values 38.54, 39.05, 40.90 and 39.26 kg P ha^{-1} at 15, 30, 45 and 60 DAI, respectively. Also, a similar trend was observed with the application of sodium molybdate. The release of available P increased with the levels of Mo. Application of sodium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) registered the highest available P at 15 (40.44 kg P ha^{-1}), 30 (40.61 kg P ha^{-1}), 45 (40.89 kg P ha^{-1}) and 60 (40.84 kg P ha^{-1}) DAI, respectively. The interaction effect of molybdenum sources and levels were significantly different. The results showed that the combined effect of sodium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) enhanced the release of soil available P over the entire incubation period.

The synergistic interaction between Mo and P can be attributed to the formation and availability of the phosphomolybdate complex through Mo fertilization. This complex conveniently provides Mo in an easily accessible form, promoting its beneficial effects on P availability in the soil (Sun and Selim, 2017). Numerous studies have consistently demonstrated that applying molybdenum enhances the availability of P in the soil. These studies have primarily attributed this effect to the synergistic interaction between Mo and P, which is facilitated by the formation of anionic complexes between these elements (Liu *et al*., 2010; Nie *et al*., 2015).

DTPA extractable Zn

The soil DTPA extractable Zn was significantly influenced by molybdenum sources and levels at each study interval (Fig 1). The DTPA extractable Zn was determined at every 15 days interval and it was observed that the release rate of DTPA extractable Zn decreased with increased levels of molybdenum for both sources. Application of sodium molybdate resulted in the decrease of mean DTPA extractable Zn from 1.40 to 1.07 mg kg^{-1}, while application of ammonium molybdate marked a decline from 1.38 to 1.08 mg kg^{-1}. The release of DTPA extractable Zn decreased with the increased levels of Mo. Among the different levels of Mo, the maximum decline was observed with the application of Mo @ 0.4 mg kg^{-1} soil (L_4) throughout the incubation period with both sources. Application of ammonium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) marked the highest decline with mean values of 1.16, 1.13, 1.10 and 1.08 mg kg^{-1} at 15, 30, 45 and 60 DAI, respectively. A similar trend was observed with the application of sodium molybdate also. The release of DTPA extractable Zn decreased with the levels of Mo. Application of sodium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) registered the least mean values at 15 (1.15 mg kg^{-1}), 30 (1.12 mg kg^{-1}), 45 (1.07 mg kg^{-1}) and 60 (1.07 mg kg^{-1}) DAI, respectively. The interaction effect of molybdenum sources and levels were significantly different. The results showed that the application of sodium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) registered the maximum decline, which is on par with the application of ammonium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) over the entire period of incubation. The results also indicated that the interaction between variables S and L (S*L) had a significant impact on the DTPA extractable Zn release in the soil at each interval of incubation. The differences between the means of S*L were significant at all levels, indicating that the combinations of variables S and L had a significant impact on the DTPA extractable Zn throughout the incubation period. Similar results were also reported by Basak *et al*. (1982).

DTPA extractable Fe

The application of different levels of Mo significantly influenced the release of DTPA extractable Fe from the soil

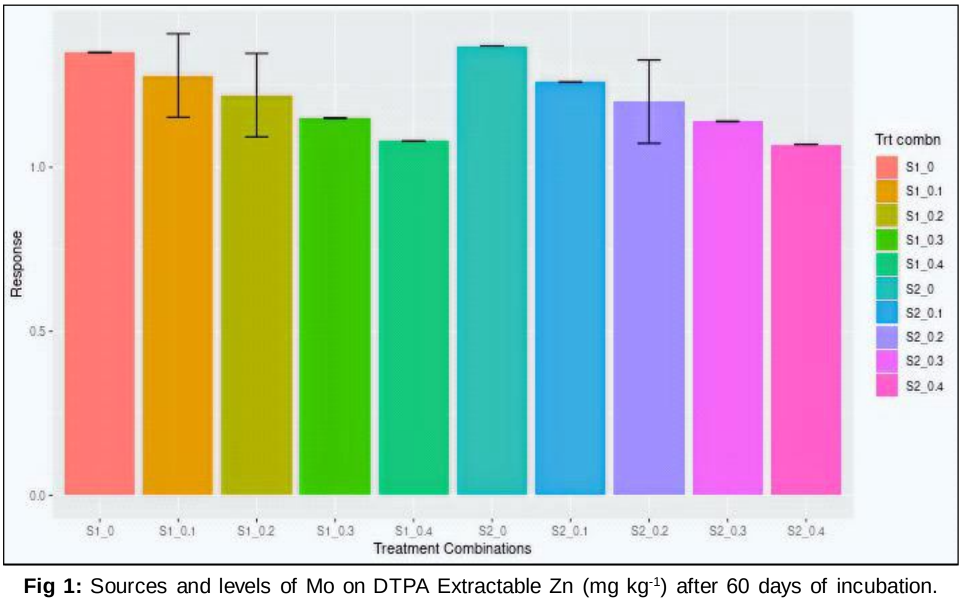

Fig 1: Sources and levels of Mo on DTPA Extractable Zn (mg kg^{-1}) after 60 days of incubation.

throughout the period of incubation study (Fig 2). The DTPA extractable Fe showed a consistent decrease with the increased levels of Mo during the entire incubation period with both S_1 and S_2. Compared with the ammonium molybdate, the application of sodium molybdate at higher doses significantly decreased DTPA extractable Fe. Application of ammonium molybdate resulted in a decline in DTPA extractable Fe from 56.08 to 50.05 mg kg^{-1}, while in the case of sodium molybdate it marked a decline from 56.14 to 49.58 mg kg^{-1}. S_1 and S_2 were significantly different from each other. The mean values for different levels showed a gradual decrease from L_0 to L_4, indicated that a negative relationship between DTPA extractable Fe and different levels of Mo. Similar to the results for S_1 and S_2, the available Fe for each level was consistently lower than those for S_2 than S_1 at each incubation interval. Among the different levels of molybdenum, the greatest decline of DTPA extractable Fe was observed with the application of Mo @ 0.4 mg kg^{-1} soil (L_4) throughout the incubation period for both sources. The differences between the means of L_0, L_1, L_2, L_3 and L_4 were statistically significant, indicating that the choice of L had a significant impact on the DTPA extractable Fe at different incubation intervals. The results also indicated that the interaction between variables S and L (S*L) had a significant impact on the DTPA extractable Fe in the soil at each incubation interval. The results showed that applying sodium molybdate at 0.4 mg Mo kg^{-1} soil (L_4) caused more decline at the end of the incubation study. Application of sodium molybdate at 0.3 mg Mo kg^{-1} soil (L_3) and ammonium molybdate at 0.4 mg kg^{-1} soil (L_4) were on par to each other at 60 DAI. The differences between the means of S*L were significant at all levels, indicating that the combinations of variables S and L had a significant impact on the DTPA extractable Fe throughout the incubation period.

One possible explanation for the decrease in iron content as the levels of Mo increase is the potential inactivation of Fe through the formation of a highly insoluble iron-molybdenum precipitate (Gerloff *et al*., 1959). Similar results were also reported by Basak *et al*. (1982).

DTPA extractable Mn

The soil DTPA extractable Mn was significantly influenced by molybdenum sources and levels at each study interval (Fig 3). The DTPA extractable Mn was determined at every 15 days interval and it was observed that the release rate of DTPA extractable Mn decreased with increased levels of Mo for both sources. Application of sodium molybdate resulted in the decrease of mean DTPA extractable Mn from 2.90 to 2.09 mg kg^{-1}, while application of ammonium molybdate marked a decline from 2.88 to 2.20 mg kg^{-1}. DTPA extractable Mn decreased with the increased levels of Mo. Among the different levels of Mo, the greatest decline was observed with applying Mo @ 0.4 mg kg^{-1} soil (L_4) throughout the incubation period with both sources. Application of ammonium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) marked a maximum decline with mean values of 2.45, 2.24, 2.21 and 2.20 mg kg^{-1} at 15, 30, 45 and 60 DAI, respectively. A similar trend was observed with the application of sodium molybdate also. Application of sodium molybdate @ 0.4 mg Mo kg^{-1} soil (L_4) registered the lowest mean values at 15 (2.32 mg kg^{-1}), 30 (2.13 mg kg^{-1}), 45 (2.10 mg kg^{-1}) and 60 (2.09 mg kg^{-1}) DAI, respectively. The interaction effect of Mo sources and levels were significantly different. The results showed that the application of sodium molybdate (S_2) @ 0.4 mg Mo kg^{-1} soil (L_4) registered the maximum decline, followed by the application of ammonium molybdate (S_1) @ 0.4 mg Mo kg^{-1} soil (L_4) over the entire period of incubation. The results also indicated that the interaction between variables S and L (S*L) had a significant impact on the DTPA extractable Mn release in the soil at each interval of incubation. The differences between the means of S*L were significant at all levels, indicating that the combinations of variables S

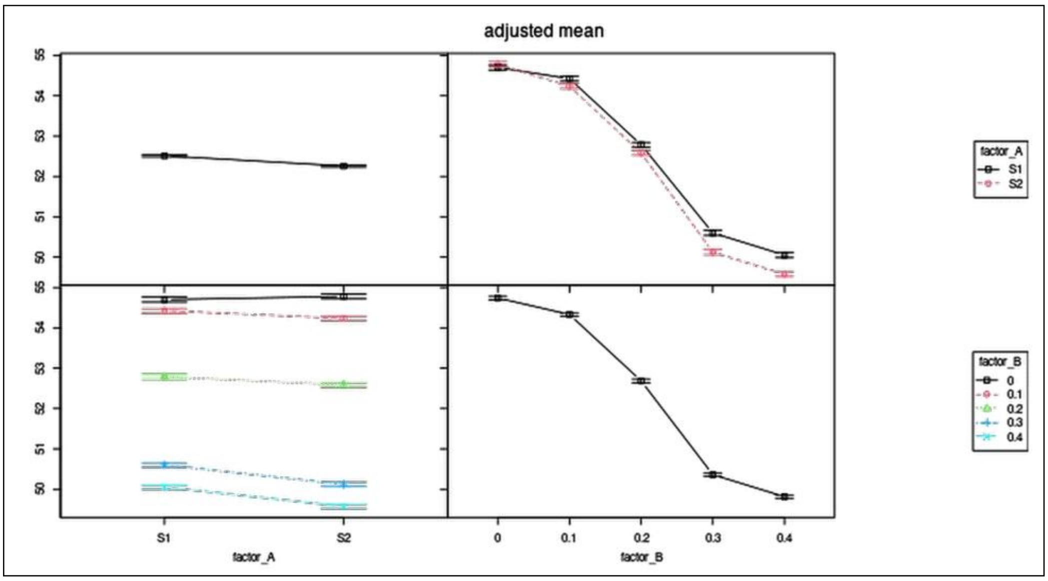

Fig 2: Sources and levels of Mo on DTPA extractable Fe (mg kg^{-1}) after 60 days of incubation.

and L had a significant impact on the DTPA extractable Mn throughout the incubation period.

The decrease in Mn content in the soil following the application of various Mo concentrations can be attributed to the formation of a low-solubility compound known as Mn-molybdate. These findings strongly showed the presence of ion antagonism between Mo and Mn in the soil. Similar antagonistic interactions between Mo and Mn were also observed by Gupta and Mehla (1979) and Basak *et al*. (1982).

DTPA extractable Cu

The application of different levels of molybdenum significantly influenced the release of DTPA extractable Cu from the soil throughout the period of incubation study (Fig 4). The DTPA extractable Cu showed a consistent decrease with the increased levels of Mo during the entire incubation period with both S_1 and S_2. Compared with the ammonium molybdate, the application of sodium molybdate at higher doses had a significant effect on DTPA extractable Cu. Application of ammonium molybdate resulted in a decline in DTPA extractable Cu from 1.98 to 1.37 mg kg^{-1}, while in the case of sodium molybdate it marked a decline from 1.99 to 1.18 mg kg^{-1}. S_1 and S_2 were significantly different from each other. The mean values for different levels showed a gradual decrease from L_0 to L_4 and a negative relationship between DTPA extractable Cu and different levels of Mo. Similar to the results for S_1 and S_2, the mean values for L were consistently lower than those for S_2 than S_1 at each incubation interval. Among the different levels of Mo, the greatest decline of DTPA extractable Cu was observed with

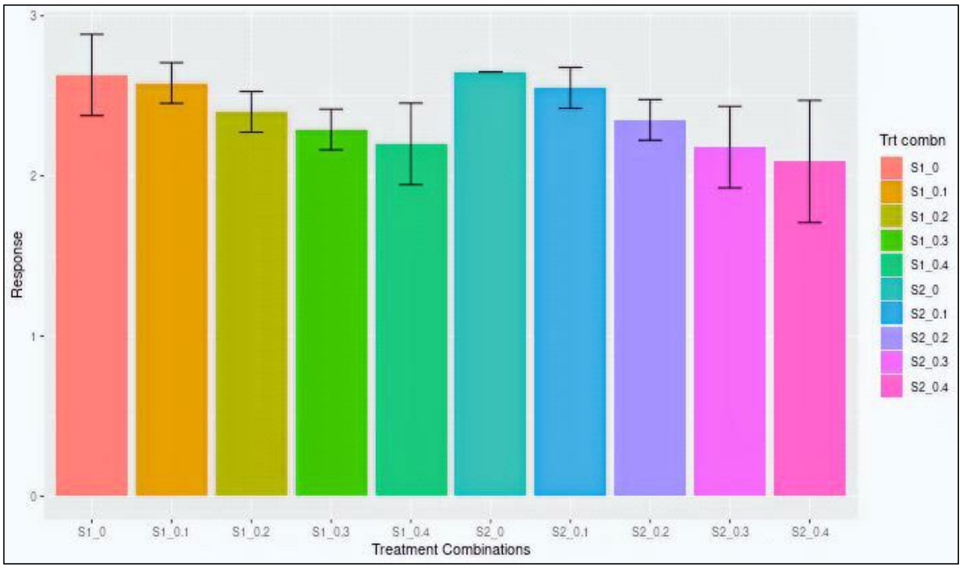

Fig 3: Sources and levels of Mo on DTPA Extractable Mn (mg kg^{-1}) after 60days of incubation.

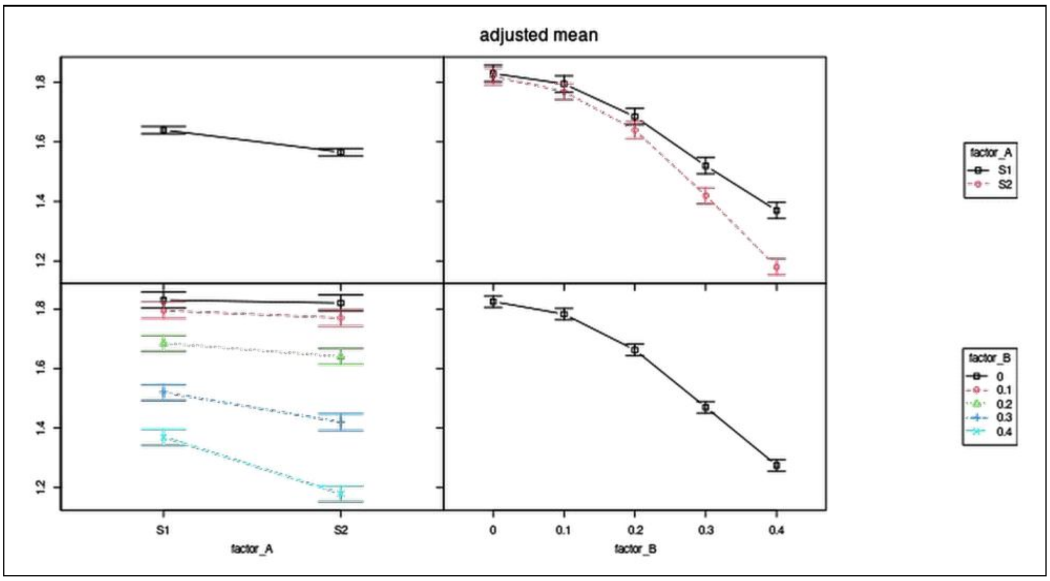

Fig 4: Sources and levels of Mo on DTPA Extractable Cu (mg kg^{-1}) after 60 days of incubation.

the application of Mo @ 0.4 mg kg^{-1} soil (L_4) throughout the incubation period for both sources. The differences between the means of L_0, L_1, L_2, L_3 and L_4 were statistically significant, which indicated that the choice of L had a significant impact on the DTPA extractable Cu at different intervals of incubation. The results also indicated that the interaction between variables S and L (S*L) had a significant impact on the DTPA extractable Cu in the soil at each incubation interval. The results showed that the application of sodium molybdate (S_2) at 0.4 mg Mo kg^{-1} soil (L_4) caused a steep decline at the end of the incubation study. Application of sodium molybdate at 0.3 mg Mo kg^{-1} soil (L_3) and ammonium molybdate at 0.4 mg kg^{-1} soil (L_4) were on par to each other at 60 DAI. The differences between the means of S*L were significant at all levels, indicating that the combinations of variables S and L had a significant negative impact on the DTPA extractable Cu throughout the incubation period.

The observed decrease in copper content could potentially be attributed to the antagonistic relationship between molybdenum and copper. Gupta and Mehla (1979) reported a notable reduction in copper content in soils upon applying molybdenum (Mo). Additionally, they highlighted the existence of antagonistic interactions between manganese and Mo within the soil. Similar antagonistic interactions between Mo and Cu were also observed (Basak *et al*. (1982).

CONCLUSION

From the experiment, it can be concluded that molybdenum significantly influenced the release of various nutrients present in the soil. It was also observed that molybdenum has a synergistic effect on available nitrogen and phosphorus, while it exhibits antagonism towards DTPA extractable micronutrients, namely Zn, Fe, Mn and Cu. Sodium molybdate has a more profound effect than ammonium molybdate due to its higher solubility. Therefore, it can be concluded that molybdenum fertilization holds great promise for enhancing the availability of macronutrients and reducing the toxicity of micronutrients in acid soils. Furthermore, it can be very helpful for better crop production under acidic soil.

Conflict of interest: None.

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