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STUDIES ON A COMPLEX SLOW RELEASE FERTILIZERS: II.IONIC COMPOUND ESTABLISHED THROUGH INTERACTION BETWEEN ESSENTIAL MICRONUTRIENTS AND UREA AND THEIR EFFECTS ON LETTUCE PLANT

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ABSTRACT

A series of laboratory and greenhouse experiments were conducted to evaluate ionic compound formed between urea and essential micronutrient through complexation reaction. Results revealed that the addition of metal salt urea without organic matter, slightly increased the pH of the soil. At the beginning of the incubation, citric acid enhanced the E.C. of the soil and gradually increased up to 28 days of the incubation. Results also showed that the addition of metal salt urea complexed improved the characterization of modified slow release fertilizers through allowing a steady hydrolysis of urea to the soil over a period of six weeks. The addition of Fe or Mn to complexes urea increased the availability of iron and manganese in the soil. Citric acid addition gave the highest value of Fe and Mn as compared without citric acid. It was observed that the addition of complexes metal salt urea with citric acid had significantly increased fresh and dry weight of the lettuce plant with gradually increased in the presence of organic matter at different stages of the growth. Higher value of fresh and dry matter production were recorded in the presence of citric acid due to improving of the fertilizer complexing salt urea mechanisms.

The application of complexing metal salt urea had a positive effect for maintaining Fe in an active form as Fe^{2+} in leaves of the lettuce plants reflecting on the increasing of chlorophyll content to an extent of healthy plants and thus the ability to overcome the adverse effects of high pH and other ions in soil and then correcting iron chlorosis particularly in newly reclaimed soil.

Keywords : Metal salt urea, pH, E.C., Urea-N, Fe, Mn, Lettuce plant.

INTRODUCTION

Urea is the most widely used as a source of nitrogen fertilizer in the world. Complex slow release fertilizers may pick up the final products through uniform application of several nutrients, and avoid distribution costs. The agronomic efficiency of urea can be improved when combined in an intimate mixture with micronutrients (Klanica and Schiessl, 1971).

In Egypt, particularly under high pH values most of micronutrients can not be available for plant due to immobilization, these elements have been incorporated into ordinary fertilizers either by admixing compounds of the micrountrients elements with the fertilizer particles or by coating the fertilizer particles with such compounds *(Lupin and Peters, 1984)*. Metal salt urea complexes are presently being investigated as possible intermediate for improving the efficiency of urea as fertilizer and as a means of introducing required trace elements into the soil (Kannan and Ramani, 1984).

Recently, some metal salt-urea complexes have been successfully prepared (Atkisson, 1981). Since the urea can be effective when complexed with certain metal salts to form new anhydrous coordination complexes. Such approach may prepare urea-based fertilizers which contain micronutrients and still maintain good physical properties during storage. Such products may also offer other advantages : reduction in urea hydrolysis and/or NH_3 volatilization (Lewis and Slater, 1979), improvement of seed germination, and at the same time supply of micronutrients to soils.

The objective of this research is to develop a new product through complexation reaction between essential micronutrients and urea forming ionic compound and their effects on lettuce plants.

MATERIALS AND METHODS

Preparation of metal salt-urea complexes:

In this study, four metal salt-urea complexes such as Fe $(urea)_6SO_4$, $Fe(urea)_6SO_4$. CA, $Mn(urea)_4SO_4$, and $Mn(urea)_4SO_4$. CA, were prepared in the laboratory as follows :

Iron urea sulphate Fe $(urea)_6$ SO_4 :

30gm of ferrous sulphate and 70 gm of urea were dissolved in minimum amount of warmed water, the solution was allowed to stand at ambient temperature for several days. During that time green precipitated of crystals were recovered by filtration, washed with methanol, and dried in a vacuo at 50°C to give green prisms.

Iron urea sulphate citric acid, Fe $(urea)_6$ SO_4 .CA :

30 gm of ferrous sulphate, 20 gm of citric acid, and 50 gm of urea in minimum amount of warmed water. The solution was cooled to 0°C. Colorless crystals were precipitated and recovered by filtration, washed with methanol, and dried in vacuo at 50°C.

Manganese urea sulphate Mn $(urea)_4$ SO_4 :

Exact weight of manganese sulphate 18.7 gm and 81.3 gm of urea were ground separately to less than 1 mm. The materials were ground together with 500 gm of 1.5 cm diameter ceramic balls and 50 mL of water for 3 h in a ball mill. Pale pink paste was formed, dried in vacuo at 50°C for 32 h to give a pale pink solid.

Manganese urea sulphate citric acid Mn $(urea)_4$ SO_4 .CA :

Exact weight of manganese sulphate 18.7 gm, 20 gm of citric acid and 61.3 gm of urea were ground separately to less than 1 mm. The materials were ground together with 500 gm of 1.5 cm diameter ceramic ball and 50 mL of water for 3 h in a ball mill. Pale pink paste was formed, dried in vacuo at 50°C for 32 h to give a pale pink solid.

Laboratory experiment :

Three hundred grams of 2 mm sieved air dry soil was characterized by pH 8.01, E.C. 0.17 dsm^{-1}, $CaCO_3$ 6.8%, organic matter 0.21%, total-N

0.012%, Clay 1.73, silt 5.59%, sand 92.68%. The soil were treated with metal salt urea at a rate of 500 mg N in wide mouth 400 mL plastic containers. The calculated nutrient in the prepared fertilizers Fe and Mn-urea are shown in table (1). The fertilizers were used as follows :

Fe $(urea)_6$ SO_4	Fe $(urea)_6$ SO_4 + 2% O.M
Fe $(urea)_6$ SO_4.CA	Fe $(urea)_6$ SO_4.CA + 2% O.M
Mn $(urea)_6$ SO_4	Mn $(urea)_4$ SO_4 + 2% O.M
Mn $(urea)_4$ SO_4.CA	Mn $(urea)_4$ SO_4.CA + 2% O.M

Treatments were replicated and kept under laboratory conditions, moisture content was maintained at 60% of water holding capacity through the incubation periods. Soil samples were taken at intervals of 1, 3, 7, 14, 28, 42, 56 and 70 days. Soil pH, E.C., NH_4-N, NO_3-N, Urea-N, Fe and Mn determined as described by Black (1982) and Bremner and Mulvaney (1982) respectively.

Table (1) : Calculated nutrient contents in the mixtures of Fe-urea and Mn-urea :

Treatment	Grams				%		
	Urea	$FeSO_4$	$MnSO_4$	Citric acid (CA)	N	Fe	Mn
Fe $(urea)_6$ SO_4	70	30	-	-	32.2	6	-
Fe $(urea)_6$ SO_4.CA	50	30	-	20	23.0	6	-
Mn $(urea)_4$ SO_4	81.3	-	18.7	-	37.3	-	6
Mn $(urea)_4$ SO_4.CA	61.3	-	18.7	20	28.2	-	6

Table (2) : Some chemical characteristics of farmyard manure applied :

PH	Organic carbon	Total nitrogen	C/N Ratio	Total phosphorus	Total potassium	Total sulphate	Available EDTA extractable feraction of micro nutrients(ppm)		
	%	%		%	%	%	Fe	Mn	Zn
7.3	20.31	1.52	13.4	0.92	1.48	1.24	212	127	98

Pot experiments :

Greenhouse experiment was conducted in the National Research Centre and designed as randomized complete block with three replicates in plastic pots 40 cm height, 25 cm diameter, each one containing 10 kg of air dried soil. Similar treatments were constracted the same as described in the laboratory experiment.

The metal salts urea were applied at a rate 100 mg N/kg soil phosphorous and potassium were applied at rates of 50 mg P_2O_5 and 40 mg K_2O/kg as superphosphate and potassium sulphate respectively. Four 21 day-old seedling of lettuce plants (Lactuca sativa L. CV. Dark Green) were transplanted in pots and kept under field capacity. Plant samples were taken after 30, 60 and 90 days of plantations. Fresh weights were recorded dried at 70°C weighted and ground to pass through a 1 mm seive. Chlorophyll, ferrous, nitrogen, phosphorous, potassium, Fe, Mn and Zn were determined according to the methods described by Cottenie *et al.* (1982) and Black (1982).

RESULTS AND DISCUSSION

Soil reaction :

Results in Fig. (1) revealed that the pH of soil for all treatments used were dissimilar, indicating that treatment had different effect on the acidity of soil. It was noticed that maximum value ranged between (8.6-8.33), however minimum value was observed between (7.6-7.7). Results showed that metal salt urea without organic matter, slightly increased the pH of soil as compared with addition of organic matter. This result may be due to the decomposition of organic matter created soluble organic acid such as fulvic and humic acid which decreased the pH of soil during the incubation period (Abou Seeda, 1997).

It was noticed that Fe (urea)$_6$ SO_4 and/or Mn (urea)$_4$ SO_4 increased the soil pH as compared with Fe(urea)$_6$$SO_4$.CA and/or Mn(urea)$_4$$SO_4$.CA particularly at the beginning of incubation, and gradually increased during the incubation period up to 28 days. This may be attributed to presence of citric (Cajuste *et al.*, 1996).

Results also showed that metal salt-urea treated with organic matter decreased soil pH particularly after one day of incubation. It was observed that the soil pH markedly increased in case of Fe (urea)$_6$ SO_4 with organic matter addition especially after 3 days of incubation. However, the citric acid treatment gradually decreased the soil pH as compared with the presence of organic matter. It was noticed that the average of treatments were increased by about 0.32 and 0.64 unit, for

Fe(urea)$_6$$SO_4$ at 14 days of incubation as compared with organic matter and citric acid respectively.

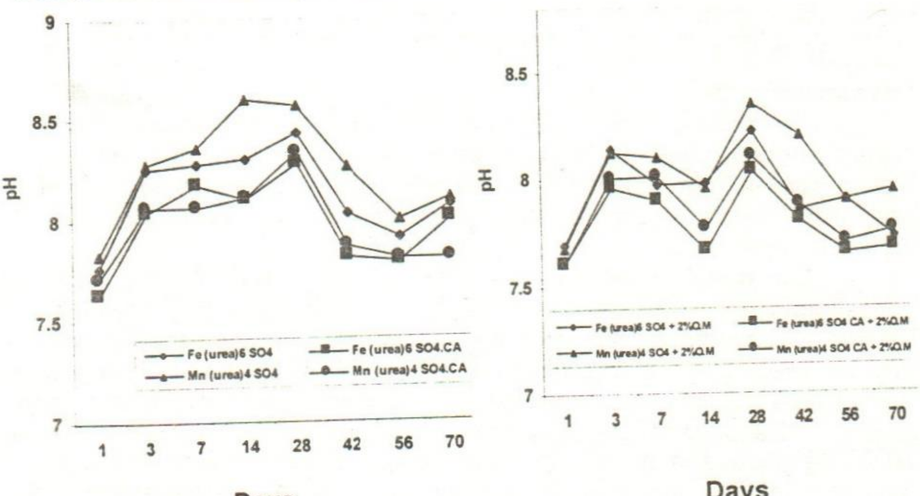

Fig. (1) : Effect of metal salt urea without and with 2% organic matter on the soil pH during the incubation periods

From the data in Fig. (2), it was noticed that the addition of metal salt urea increased the E.C. of the soil gradually up to 28 days of the incubation. Organic matter addition to metal salt urea treated soil was more pronounced effect on the electrical conductivity of the soil as compared without organic matter addition. This result may be attributed to the action of organic acids and some other organic compounds that are produced during decomposition (Abou Seeda *et al.*, 1997).

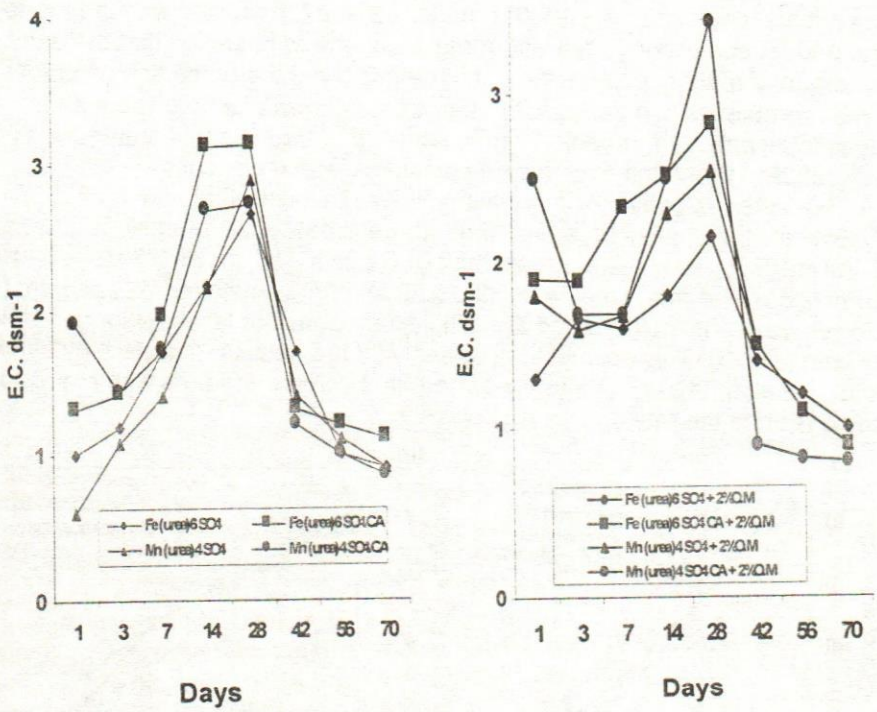

Fig. (2) : Effect of metal salt urea without and with 2% organic matter on the electrical conductivity of the soil (EC ds.m^{-1})

At the beginning of the incubation the treatments with citric acid enhanced the E.C. of the soil. The role of the citric acids for inhibiting the evaluation of ammonia which increase the electrical conductivity of the investigated soil and gradually increase in the presence of organic matter added. Results also showed that the application of Mn (urea)$_4$ SO_4. CA with or without organic matter added was more remarkable effect on the E.C. of the soil. Fox and Comerford (1990) and Cajuste *et al.* (1996) reported that such phenomenon may be related to the structure of the organic molecule and the ability of citrate and organic matter to form stable complexes with Mn and urea through a ligand-exchange reaction.

During the incubation period sharp decreased in the electrical conductivity was observed and also no differences between the treatments particularly at the end of experiments.

Urea-N transformation :

Four modified metal salt urea complexing materials in this experiment improving the character of modified slow release fertilizers through allowing a steady hydrolysis of urea to the soil over a period of six weeks (Fig. 3). The diffusion rate of urea products varied greatly depending on physical, chemicals characteristics of the materials and the reacted with urea to form the adduct complexing urea with metal salts. It was observed that the addition of organic matter with metal salt urea improved the properties of metal salt urea complexes comparing with other treatments without organic matter. The beneficial effect of organic matter with citric acid treated material may be attributed to formation of stable complex urea with metal salts.

After 42 days of incubation it was noticed that about 3.2, 5.9 and 12.3% of the applied urea remained for $Fe(urea)_6SO_4$, $Fe(urea)_6SO_4$.CA and $Fe(urea)_6SO_4$. CA+ O.M., respectively. Results also showed that the treated complex metal salt urea with citric acid and organic matter released urea at slower rate and thus allowed the initial linear phase to last for a longer period of time (Fig. 3). This observation agrees with the results obtained by Lewis and Salter (1979) they reported that complexing urea with metal salts could reduce the rate of urea hydrolysis in soils.

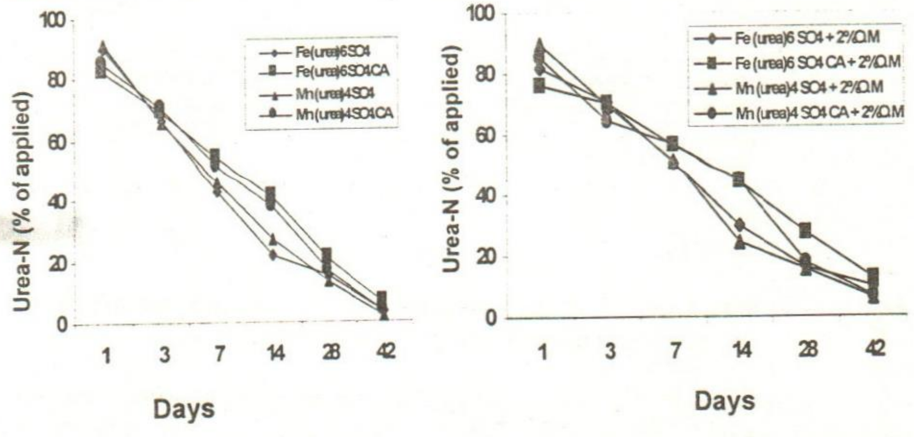

Fig. (3): Effect of metal salt urea complexing compained with organic matter on urea hydrolysis during the incubation period (urea-N % of applied)

Urea hydrolysis fig (3) is characterized by several stages, the initial wetting of urea complexing is the first followed by a linear phase of hydrolysis which characterized by high hydrolysis rate, the final stage is a reduced rate phase occurred after approximately two/thirds of the complexing urea with metal salts had hydrolysed.

Total inorganic nitrogen :

The effect of metal salt urea complexing on the release of total inorganic nitrogen through the incubation period are illustrated in Fig.(4). It was observed that the addition of Fe (urea)$_6$ SO_4 increased the total inorganic nitrogen through the first week. Whereas the application of Fe (urea)$_6$ SO_4. CA regulate the release of total inorganic nitrogen up to 28 days and then decreased gradually up to 70 days of incubation. This results suggested that the addition of citric acid during the preparation of the complexing materials was more effective than Fe (urea)$_6$ SO_4 alone for binding sorbing sites on the exchange complex and the ability of citrate to form stable complexes with Fe and urea of soils, and therefore regulate the release of total inorganic nitrogen similarly were observed by (Fox and Comerford, 1992).

Similar trends were noticed in case of Mn (urea)$_4$ SO_4 or Mn (urea)$_4$ SO_4 CA. The increase in the total inorganic nitrogen released indicates that the reactive sites of chelating compound are being released and are available for NH_4 + NO_3 reaction, the mechanism of chleting compound adsorption involves ligand exchange (Parfitt *et al.*, 1977). These findings are in agreement with the previous studies that indicate a blocking effect on reactive sites produced by these organic polymers (Sibanda and Young, 1986 and Mora et al., 1992a).

Concerning the addition of organic matter to metal salt urea, it was noticed that application of organic matter was more pronounced effect on the administer of total inorganic nitrogen through the incubation period. The addition of organic matter to Fe (urea)$_6$ SO_4. CA was more effective in the regulation of total inorganic nitrogen than other treatments. Results also showed that about 206.4 ppm were remained particularly after 70 days of incubation, and the percentage rate of increasing were 24.11% and 10.07% at 42 and 70 days for Fe (Urea)$_6$ SO_4. CA + O.M as compared with Fe (urea)$_6$ SO_4. CA. This result may be attributed to the organic matter, which may act as a template for metals complexation and binding, both two mechanisms increase inorganic nitrogen adsorption capacity (Tsutsuki and Kuswatsuka, 1992). It is possible that the humin-metal complexes in the presence of organic matter added are forming with polymerized and monomeric Fe species (Inoue, 1990).

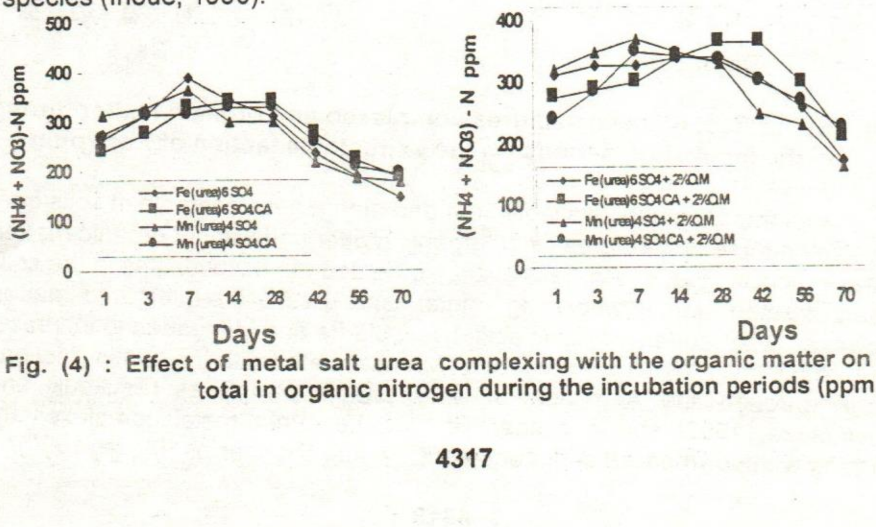

Fig. (4) : Effect of metal salt urea complexing with the organic matter on the total in organic nitrogen during the incubation periods (ppm)

The extractable fractions of Fe and Mn :

The extractable fractions of Fe and Mn are plotted versus time for different complexing metal salt urea treatments (Fig. 5 and 6). It was observed that the addition of Fe (urea)$_6$ SO_4 and Mn (urea)$_4$ SO_4 with citric acid added gave the highest value of Fe and Mn as compared with the other treatments without citric aid added. The availability of Fe and Mn with organic matter added were remarkably higher than without organic matter added. The increase in both Fe and Mn mobilized in organic matter treated materials could be attributed to the formation of carboxilic acids substances e.g. humic and fulvic acid that improve the absorption capacity and also increase the mobilizable fraction of Fe and Mn as well. Parfitt *et al.* (1977) reported that the mechanism of humic and fulvic acid adsorption involves ligand exchange.

It was observed that the application of Fe or Mn to complexes urea increased the availability of iron and manganese in soil during the incubation periods. Available Fe and Mn increase with increasing the incubation period and thereafter either remained constant or declined slightly which probably due to completion of conversion processes of higher oxides of Fe and Mn to their divalent forms (Borges-Perez *et al.*, 1994).

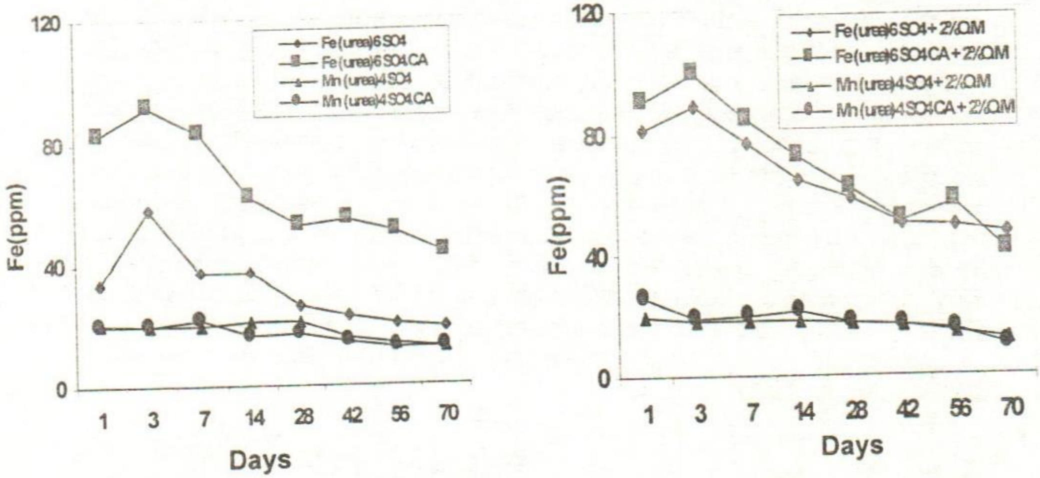

Fig. (5) : Effect of metal salt urea complexed and organic matter during the incubation periods on the extractable faction of iron (ppm)

Comparing the available iron and manganese contents of soils from complexing metal salt urea with organic matter and without organic matter, data indicated that much less available Fe and Mn accumulates in the soils when treated with complexing metal salt urea without organic matter. However with addition of citric acid, available Fe and Mn tended to increase. The result may be due to Fe and Mn associated with the humin fractions occur through the formation of very stable complexes (Tsuksuki and Kuwatsuka, 1992) and it is possible that the humin-metal complexes are forming with polymerized and monomeric Fe and Mn species (Inoue, 1990).

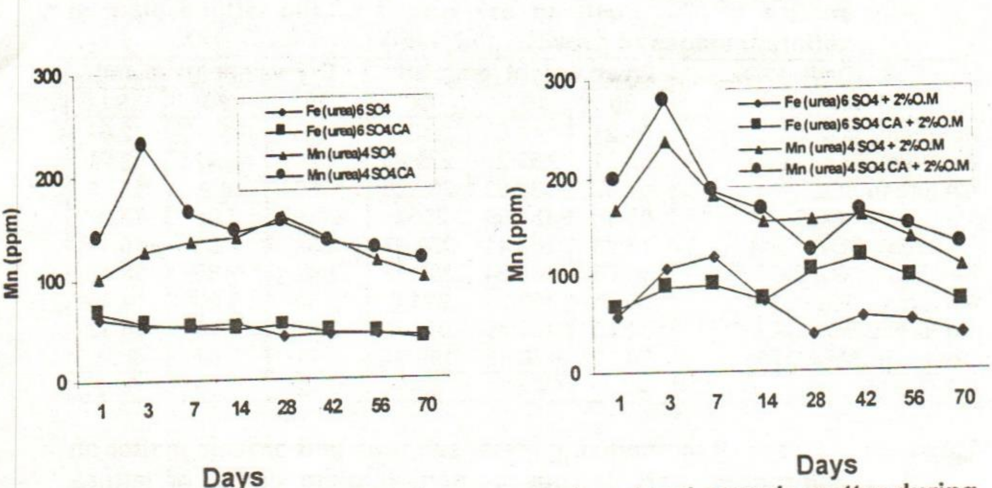

Fig. (6) : Effect of metal salt urea complexed and organic matter during the Periods, on the extratable fraction of manganese (ppm)

Plant growth :

The application of metal salt urea with or without organic matter on the fresh and dry weight of lecttuce plants are presented in table (3). It was observed that the addition of complexes metal salt urea with citric acid had significantly increased the fresh and dry weight of the lettuce plants at different stages of the growth. The ameliorative effect of citric acid depends on its reactions of urea with binding sorbing sites on the exchange complex to form stable complexes with Fe and/or Mn and consequently, have a major functional acidic group product that maintain Fe and/or Mn more available through increasing its solubility groups. Similarly were noticed by (Mora *et al.*, 1993). It was observed that the addition of metal salt urea with citric acid and organic matter were more pronounced effect on both fresh and dry weight at 30, 60 and 90 days of experiment. The addition of citric acid with complexing urea resulted in a remarkable effect on the fresh and dry weight by about 24.3, 22.5, 8.9 and 13.3% at 90 days for Fe $(urea)_6$ SO_4 CA and Mn $(urea)_4$ SO_4. CA as compared without citric acid. While the addition of Fe $(urea)_6$ SO_4 and/or Mn $(urea)_4$ SO_4 with organic matter improved the fresh and dry weight of lettuce plant during the experiment. The percentage rate of increasing were 9.03, 15.66, 40.94, 35.7% and 21.76, 24.61, 16.53, 22.1 for fresh and dry weight at 60 and 90 days respectively as compared without organic matter.

Table (3) : Effect of complexing metal salt urea with and without organic matter on the fresh an dry weight of the lettuce plant at different stages of growth (gm/plant)

Days / Treatments	Fresh weight (gm/plant)			Dry weight (gm/plant)		
	30	60	90	30	60	90
Fe (urea)$_6$ SO$_4$	61.21	148.65	212.0	1.85	5.5	12.67
Fe (urea)$_6$ SO$_4$.CA	69.21	152.29	279.89	2.24	6.42	13.91
Mn (urea)$_4$ SO$_4$	54.37	137.39	206.85	1.63	4.9	11.45
Mn (urea)$_4$ SO$_4$.CA	63.98	151.66	266.6	2.19	6.03	13.21
Fe (urea)$_6$ SO$_4$ + O.M	73.83	163.41	358.97	2.34	7.03	15.18
Fe (urea)$_6$ SO$_4$. CA + O.M	96.73	175.34	387.12	2.42	7.80	18.47
Mn (urea)$_4$ SO$_4$ + O.M	69.45	162.91	321.8	2.32	6.50	14.70
Mn (urea)$_4$ SO$_4$. CA + O.M	84.15	163.49	361.0	2.41	7.10	16.12
Urea + Fe, Mn-EDTA	50.11	130.12	199.34	1.21	2.57	9.64
L.S.D. 5%	4.31	2.62	5.42	0.12	0.39	0.92

Table (4) : Effect of complexing metal salt urea and organic matter on chlorophyll and ferrous content (mg/gm dry.w) of lettuce plants

Days / Treatments	mg/gm d.wt.			
	Total chlorophyll		Fe^{2+}	
	30	60	30	60
Fe (urea)$_6$ SO$_4$	15.0	9.4	0.29	0.48
Fe (urea)$_6$ SO$_4$.CA	17.5	11.3	0.35	0.52
Mn (urea)$_4$ SO$_4$	9.0	4.5	0.20	0.30
Mn (urea)$_4$ SO$_4$.CA	10.5	4.5	0.20	0.31
Fe (urea)$_6$ SO$_4$ + O.M	24.6	15.0	0.45	0.66
Fe (urea)$_6$ SO$_4$. CA + O.M	28.9	19.5	0.77	0.97
Mn (urea)$_4$ SO$_4$ + O.M	10.0	7.0	0.21	0.30
Mn (urea)$_4$ SO$_4$. CA + O.M	12.5	7.5	0.25	0.32
Urea + Fe, Mn-EDTA	6.5	3.0	0.18	0.20

The addition of organic matter to metal salt urea complex was more pronounced effect for increasing the fresh and dry weight of lettuce plants but the highest rate of increase was recorded when citric acid was added as a chelating compound. After 90 days the rate of increase in fresh and dry weight reached 48.5 and 47.8% for Fe (urea)$_6$ SO$_4$. CA + O.M as compared with urea + Fe, Mn-EDTA respectively. While, Fe (urea)$_6$ SO$_4$. CA increased fresh and dry weight more than urea + Fe, Mn-EDTA after 60 and 90 days by about 14.55, 28.77, 59.9 and 30.69% respectively.

Total chlorophyll and ferrous content:

a. Total chlorophyll content:

Chlorophyll content as a measure of Fe-stress in plants is presented in table (4). It was noticed that the addition of Fe (urea)$_6$ SO$_4$ with or without citric acid increased the total chlorophyll content as compared with urea + Fe and/or Mn-EDTA. The addition of citric acid to metal salt urea enhanced the chlorophyll content in leaves due to the role of citric acid for maintaining Fe in available form as observed in Fig. (5).

Among the different treatments applications of metal salt urea [Fe(urea)$_6$SO$_4$] increased the chlorophyll of lettuce leaves, due to the availability of iron to the plant. This result may be due to when the plant was allowed to take up NH_4, due to ammonification, a localized drop in the pH occurred in the rhyzosphere zone due to NH_4 uptake. This change of pH in the rhyzosphere was sufficient to mobilize enough Fe^{2+} near the root to allow Fe uptake by the plant (Kafkafi and Ruth, 1985).

b. Ferrous content :

Concerning ferrous leaves content, the results in table (4), also indicated that in general all the Fe (urea)$_6$ SO_4 complexing had positive effect on ferrous leaves content of lettuce plants at the different stages of the growth. The effect of citric acid as ligands which are capable to form stable complexes with iron sulfate and urea was more effective effects in the availability of ferrous to the plant.

With respect to the addition of organic matter, it was observed that the addition of organic matter had matching ameliorative effect in ferrous leaves content. Results also observed that a good relation between the chlorophyll content and the ferrous content in the plant tissue as noticed in table (4).

It may be concluded that the application of complexing metal salt urea had a positive effect for maintaining Fe in an active form as Fe^{2+} in leaves of the lettuce plants reflecting on the increasing of chlorophyll content to an extent of healthy plants and thus the ability to overcome the adverse effects of high pH and other ions in soil and then correcting iron chlorosis.

Nutrient uptake by plant:

Data in tables (5 and 6) revealed that the uptake of N, P, K, Fe, Zn and Mn by lettuce plants were influenced by adopted treatments during the growing season. The magnitude variations of N, P, K, Fe, Zn and Mn uptake with respect to metal salt urea compelxing were very clear. Results revealed that the application of Fe (urea)$_6$ SO_4 and Mn (urea)$_4$ SO_4 had slightly increased the nitrogen content in plant tissues, while N-uptake was more pronounced by the addition of citric acid. This result could be explained on the basis of the positive effect of citric acid on the nitrogen absorption which may be associated with the acidulation effect of these compound on the native organic matter and subsequent release of inorganic form of N-utilizable by plant (Nograle *et al.*, 1991).

It was observed that the addition of organic matter to the soil increased total-N uptake by lettuce plant due to the beneficial effect of organic matter in improving the nutritional status particularly nitrogen form in the soil.

Results also revealed that the addition of metal salt urea increased phosphorous and potassium amounts in the tissues of lettuce plant. It was noticed that metal salt urea application combined with organic matter, stimulate the accumulation of nutrient elements in lettuce plant through the growing season as compared with the addition of metal salt urea alone. This might be due to synergistic effect between complexing salt urea and the addition of organic matter for increasing available P, K, Fe, Zn and Mn status.

Table (5) : Effect of complexing metal salt urea with and without organic matter on N, P and K uptake (mg/plant) by lettuce plants

Treatments	30			60			90		
	N	P	K	N	P	K	N	P	K
Fe (urea)$_6$ SO$_4$	38.1	2.96	37.1	124.3	11.5	143.5	263.6	44.3	415.6
Fe (urea)$_6$ SO$_4$.CA	51.7	4.92	48.3	161.1	16.0	213.1	347.9	55.6	503.6
Mn (urea)$_4$ SO$_4$	27.7	2.11	32.6	93.1	9.3	102.9	219.4	30.9	335.1
Mn (urea)$_4$ SO$_4$.CA	47.5	4.38	46.4	144.1	13.8	186.3	318.7	51.5	453.4
Fe (urea)$_6$ SO$_4$ + O.M	60.1	7.95	52.8	196.1	25.3	313.5	570.9	68.3	587.6
Fe (urea)$_6$ SO$_4$. CA + O.M	73.5	11.8	58.5	269.1	39.0	360.3	701.0	96.0	754.8
Mn (urea)$_4$ SO$_4$ + O.M	55.9	5.56	52.2	170.3	18.8	269.7	535.0	61.7	539.4
Mn (urea)$_4$ SO$_4$. CA + O.M	64.3	8.67	55.1	208.7	28.4	318.7	617.3	75.7	663.1
Urea + Fe, Mn-EDTA	22.3	1.21	24.3	86.7	7.5	98.3	202.4	24.6	303.1

Table (6) : Effect of complexing of metal salt urea with and without on Fe, Zn and Mn uptake (mg/plant) by lettuce plant

Treatments	30			60			90		
	Fe	Zn	Mn	Fe	Zn	Mn	Fe	Zn	Mn
Fe (urea)$_6$ SO$_4$	0.81	1.0	0.8	3.6	3.6	3.1	14.5	9.6	8.4
Fe (urea)$_6$ SO$_4$.CA	1.1	1.3	1.0	4.4	4.2	3.9	17.3	10.8	9.8
Mn (urea)$_4$ SO$_4$	0.5	0.6	0.9	2.4	2.2	3.6	7.6	8.0	9.5
Mn (urea)$_4$ SO$_4$.CA	0.7	0.8	1.4	3.1	3.3	4.5	12.2	9.9	13.2
Fe (urea)$_6$ SO$_4$ + O.M	1.2	1.7	1.1	6.2	5.1	4.7	22.6	13.3	10.7
Fe (urea)$_6$ SO$_4$. CA + O.M	1.4	2.1	1.1	7.2	7.7	5.3	40.8	19.3	14.2
Mn (urea)$_4$ SO$_4$ + O.M	0.9	1.4	1.5	3.3	4.4	5.3	14.7	12.3	19.4
Mn (urea)$_4$ SO$_4$. CA + O.M	0.9	1.6	1.6	3.7	5.0	6.3	16.2	13.8	28.8
Urea + Fe, Mn-EDTA	0.3	0.4	0.5	1.3	0.9	1.4	8.3	4.5	4.1

Results also observed that the effect of organic matter combined with metal salt urea were more pronounced effect on the uptake of Fe, Zn and Mn especially after 60 and 90 days of plantation. This phenomena could be explained by the regulation of nutrient release from metal salt urea combined with organic matter which play an important role for ensuring efficient utilization of Fe, Zn and Mn interaction, or the integrated management of the Fe, Zn and Mn (Nagrale *et al.*, 1991) similar view was earlier reported by (Kafkafi and Ruth, 1985; Mora and Canales, 1995 and Cajuste et al., 1996).

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دراسات على الأسمدة المركبة بطيئة الذوبان
٢- إنتاج مركبات أيونية من خلال التفاعل بين العناصر المغذية الصغرى واليوريا وتأثيرها على نبات الخس

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أقيمت عدة تجارب معملية وزراعية كان الهدف منها تقييم المركبات الأيونية المنتجة من خلال التفاعل الأيونى بين سماد اليوريا وبعض العناصر المغذية الصغرى، حيث تشير النتائج إلى :

- أدت إضافة سماد معقد اليوريا المركب (Metal salt urea) إلى حدوث زيادة طفيفة فى درجة الحموضة والقلوية (pH) للتربة.
- فى بداية تجربة التحضين إضافة حامض الستريك (Citric acid) أدى إلى حدوث زيادة فى درجة التوصيل الكهربى (E.C) للتربة والتى زادت تدريجيا حتى ٢٨ يوما من فترة التحضين.
- كما أشارت النتائج إلى انخفاض معدل التحلل لليوريا نتيجة إضافة معقد اليوريا المركب والذى انعكس على تحسين صفات سماد اليوريا المركب بطئ الذوبان، كما أدت إضافة الحديد والمنجنيز إلى معقد اليوريا إلى زيادة تيسر عنصر الحديد والمنجنيز فى التربة، بينما أدى حامض الستريك إلى زيادة قيم الحديد والمنجنيز الميسرة فى التربة مقارنة للمركبات التى لم يضاف لها حامض الستريك.
- أدت إضافة معقد اليوريا المركب مع حامض الستريك إلى حدوث زيادة معنوية فى كلا من الوزن الطازج والجاف لنبات الخس خلال مراحل النمو المختلفة (٣٠، ٦٠، ٩٠ يوم)، فى حين أدت إضافة المادة العضوية إلى معقد اليوريا إلى تفوق كلا من الوزن الطازج والجاف لنبات الخس عن باقى المعاملات.
- كما أظهرت النتائج إلى أن إضافة معقد اليوريا المركب أدى إلى حدوث تأثير ايجابى فى المحافظة على عنصر الحديد فى صورة نشطة (Fe^{2+}) والذى انعكس تأثيره من خلال زيادة محتوى الكلوروفيل فى الأوراق وظهور النباتات بحالة صحية جيدة وعلى مقاومة الـ pH العالى من خلال تصحيح ظهور نقص الحديد على النبات خاصة فى الأراضى حديثة الاستصلاح.