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IRON, MANGANESE AND COBALT UPTAKE AND CARBOHYDRATES DISTRIBUTION THROUGH CORN PLANT ORGANS

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ABSTRACT

A greenhouse experiment was conducted to study the response of corn plant to foliar application of cations , i.e., iron (Fe) and manganese (Mn) at different rates of 100 mg/L , 200 mg/L and 400 mg/L as well as cobalt (Co) at rates of 25 mg/L, 50 mg/L and 100 mg/L along with the interactions between them, i.e.,(Fe+Mn) ,(Fe +Co), (Mn+Co) and (Fe+ Mn +Co). Each combined pair of elements that tested for interactions were applied at two rates.

Results revealed that application high rate of Fe generally decreased dry matter production of leaves, root and consequently *total plant dry weight of corn.* Applying high rates of Mn and Co caused adverse effect for leaves as compared to the control. Also , the combined treatments increased the dry matter production of different corn plant organs in spite of the relatively adverse effect for interaction between (Fe+Mn).

Data also revealed that Fe,Mn and Co treatments, individually or in combination with different rates, generally increased their uptake by different plant organs as compared to control treatment .In addition the tested heavy metals Fe , Mn and Co were accumulated in root as compared to either leaves or stem .

However, excessive supply of Fe,Mn individually and/or combined with them decreased Fe uptake by leaves and root. The opposite trend was true when cobalt was applied with different rates . Also ,high rate of combined interactions between both (Fe+Mn),(Fe+Co) and (Fe+Mn+Co) show a positive effect on Fe uptake by root as compared to leaves and/or stem .

Generally, Mn uptake by total plant and different plant organs were decreased as a result of foliar application with high rates of Fe and Mn; the opposite - trend was true when Co applied with different rates for both leaves and root. The interaction treatments (Fe+Mn) shows a negative effect on Mn uptake by corn plant organs (leaves, stem and root) .High rate of double and triple interactions were accumulated Mn in both stem and total corn plants.

Finally, carbohydrate fractions content (total carbohydrate (TC), soluble carbohydrate (SC) and insoluble carbohydrate (ISC) generally increased in different plant organs (leaves, stem and root) as affected by applied Fe,Mn and Co either individually or combined with them as compared to control treatment .In general , high rate of Fe decreased carbohydrate fractions content in both leaves and stems. Similar trend was obtained for different plant organs when Mn was applied with high rate which decreased TSC and NSC distribution. The high rate application of Co increased and accumulated carbohydrate fractions in both leaves and stem. Interaction effects of studied heavy metals (Fe, Mn and Co) were hazard for all carbohydrate fraction for different plant organs.

Keywords:-iron, manganese, cobalt, uptake corn plant , nutrients and plant growth ,nutrients interaction , carbohydrate fractions content in plant.

INTRODUCTION

Iron and manganese are essential elements for plant growth, while cobalt is essential for animals and micro-organisms .

Iron plays a special role in the behavior of several trace elements and is considered as the key metal in energy transformations needed for syntheses and other life processes of the cells. Also, Mn is essential micronutrient imported actively in the chloroplasts, participating in the structure of different photosynthetic proteins and enzymes. Cobalt is thought to has a regulatory effect on some plant processes such as N_2 - fixation and vitamin B_{12} accumulation (Liu *et al.*,1998) . Cobalt has been reported that it indirectly associated with several enzymes, coenzymes, growth and metabolism of plants depend on its availability in growth medium (Marschner,1995).

However, both Fe uptake and transport between plant organs are highly affected by several plant and environmental factors, such as soil pH and ratios of several heavy metals are the most pronounced; these heavy metals decreased the uptake of Fe and its translocation to leaves along with influencing the activity of iron enzymes (Agarwala *et al.*,1977) .On the other hand, plant availability of Mn depends on soil adsorption and on root exudates for Mn chelation or reduction. Great Mn tolerance is associated with restricted absorption, restricted translocation of excess Mn to the shoots ,or great tolerance to high Mn levels within the plant tissue (El-Jaoual and Cox,1998). Cobalt active uptake mechanism is supported by the sensitivity of uptake to metabolic inhibitors (Colclasure and Schmid,1974). Divalent cations such as Ni^{2+},Cu^{2+} and Fe^{2+} also inhibit Co (Dirilgen and Inel,1994).

In larger concentration the toxic effect of excess Fe , Mn and Co ,on the other hand ,are accumulated in different parts of the plant after they are absorbed by the root system, and resulted in retardation of plant growth. This could be due to their interference with the activities of a number of enzymes essential for normal metabolism and development processes (Van Assche and Clijsters,(1990). Manganese toxicity is associated with increased Mn absorption by plant roots, rapid translocation of Mn from roots to shoots, or localized accumulation of oxidized Mn in leaves; excess of Mn seems to be particularly damaging to chloroplasts (Fernandes and Henriques ,1991 and Mukhopadhyay and Sharma ,1991).Also, excess Co increased concentration in different plant parts, maximum was in roots and minimum in fruits (Chatterjee and Chatterjee ,2003) along with decrease in net photosynthesis resulting in low production of photosynthates disturbed structural integrity of chloroplast and depressed iron porphyrin enzymes (Vanselow,1965).

Moreover,the interaction between different heavy metals were also reported by El-Jaoual and Cox (1998) who found that, the most pronounced symptom is the ratio of Fe to other elements and heavy metals in particular. The proper Fe/Mn ratio seems to be the most obligatory factor in the tolerance of plants to Fe toxicity. Excess Mn can affect unfavorably the Fe action in tissues, catalyzing the oxidation of the physiologically active Fe^{2+} to the inactive Fe^{3+} form .

Also, El-Jaoual and Cox(1998) stated that plants high in Fe and Ca may tolerate higher internal levels of Mn ,perhaps by restricting Mn transport to the shoots or by preventing localization of Mn into toxic spots.

In fact ,the presence of variable concentration of micronutrients in the growing medium has been experienced to change the cobalt status of several plant species (Dekock ,1956 and Patel *et al.*, 1976).

Pandey and Sharma (2002) found that exposure of plants to excess Co^{2+} supply led to significant decrease in Fe in root, stem and leaves.

Patel *et al.*(1976) and Chatterjee and Chatterjee (2003) reported that in different parts of tomato with an increase in Co concentration there is concomitant decrease in iron content that might due to the competition between Co and Fe for the same physiological binding sites as has been suggested by Mengel and Kirkby (1987).

On the other hand, Rauser (1978) and Rauser and Samarkoon (1980) have observed that exposure of bean seedlings to heavy metals was responsible for accumulation of carbohydrates in fully expanded leaves and was due to more photo- assimilate exports via vein loading. Khan *et al.*(2000) ,also, found that increased concentration of carbohydrates in shoots and roots of corn plant in response to Mn treatment ; carbohydrate concentration was higher in roots than in shoots.

However, Chatterjee and Chatterjee (2003) stated that in excess Co treated tomato, the accumulation of non-reducing sugars and starch was almost not altered by any of the ameliorative treatments and this might be the consequence either of impaired carbohydrate metabolism at the site of production (the sources) or of low demands at the sink sites and thus responsible for inhibited growth.

Therefore, this work aims to evaluate the effect of foliar application with different rates Fe, Mn and Co along with their interaction effects between them, foliarly applied, on their uptake and carbohydrate fractions content by corn plant grown on a sandy soil.

MATERIALS AND METHODS

A greenhouse experiment was carried out on a sandy soil collected from the farm of Ismaeliya Agric. Res. Station to study the effect of Fe, Mn and Co as foliar application on their uptake by corn plant and its component. Some physical and chemical properties of the used soil are presented in Table (1).Particle size distribution was determined by the pipette method (Piper 1950). Organic carbon percent was determined according to Page, 1982. Electrical conductivity and soluble ions were analyzed in soil paste extract according to U. S. Salinity Laboratory Staff (1954). Available nitrogen was determined according to Jackson (1973).The available P, K, Zn, Fe, Mn ,Cu and Co were determined in ammonium bicarbonate-DTPA soil extract (Soltanpour, 1985).

Pots were filled with ten Kilograms of the selected soil sample. The experiment was arranged in randomized complete block design with three replicates, control treatment being taken into consideration. Ten grains of corn (*Zea mazs L.*, cv Giza 10) were planted, developed one week old seedlings being then thinned to five plants per pot. All pots received inorganic fertilizer including ammonium nitrate (33.5%N), superphosphate (15% P_2O_5) and potassium sulphate (48% K_2O) with recommended doses 120 ,30 and 48 Kg/fed of N, P_2O_5 and K_2O,respectively. .

Table (1): Some physical and chemical properties of the experiment soil

Soil characteristics			
Particle size distribution (%)		Cations and anions in sat.extract (meq/L)	
Coarse sand	77.11	**Soluble cations meq/l**	
Fine sand	12.60	Ca^{++}	0.87
Silt	2.09	Mg^{++}	0.77
Clay	8.20	Na^{+}	1.81
Texture class	Sand	K^{+}	0.35
$CaCO_3$ %	3.40	**Soluble cations meq/l**	
OM %	0.42	CO_3^{--}	-
pH(1:2.5 soil suspension)	7.50	HCO_3^{-}	1.50
EC dS/m(in paste extract)	0.37	Cl^{-}	1.25
Soil saturation water (%)	24.2	$^*SO_4^{--}$	1.05
Available nutrients (mg/Kg)			
N	96.0	Mn	1.4
P	30.0	Zn	0.21
K	120	Cu	0.23
Fe	1.80	Co	0.07

$^*SO_4^{--}$ was determined by difference

Nitrogen quantity was divided into two doses, the first was practiced at the sowing, the second being applied one month later. Both phosphorus and potassium were added before sowing. Irrigation was practiced as needed to keep the soil moisture close to field capacity.

Iron, Manganese and Cobalt were sprayed, individually or in combinations, respectively, at 30 and 40 days after sowing.

The experiment included seven treatments as follows as well as control:

1. Iron as $FeSO_4$ at a rates of 100,200 and 400 mg Fe/L (Fe1, Fe2 and Fe3) respectively.
2. Manganese as $MnSO_4$ at a rates of 100,200 and 400 mg Mn/L (Mn1, Mn2 and Mn3) respectively.
3. Cobalt as $CoSO_4$ at a rates of 25, 50 and 100 mgCo/L (Co1, Co2 and Co3) respectively.
4. Combination between Fe + Mn at rates of
   i) 100 mg/L Fe + 100 mg/L Mn($FeMnR_1$)
   ii) 200 mg/L Fe + 200 mg/L Mn ($FeMnR_2$)
5. Combination between Fe + Co at rates of
   i)100 mg/L Fe + 25 mg/L Co ($FeCoR_1$)
   ii) 200 mg/L Fe + 50 mg/L Co ($FeCo R_2$)
6. Combination between Mn + Co at rates of
   i)100 mg/L Mn+ 25 mg/L Co ($MnCoR_1$)
   ii)200 mg/L Mn + 50 mg/L Co ($MnCoR_2$)
7. Combination between Fe+ Mn + Co at rates of
   i) 100 mg/L Fe + 100 mg/L Mn + 25 mg/L Co $(FeMnCo)_1$
   ii) 400 mg/L Fe + 400 mg/L Mn + 100 mg/L Co $(FeMnCo)_2$

Plant samples were taken after 60 days from planting and separated into leaves , stems and roots. Dry matter contents of different plant organs were recorded after oven drying at 70 ^{0}C till constant weight . Plant samples were milled and digested using a sulfuric acid and hydrogen peroxide as described by Cottenie *et al.* (1982) and subjected to the determination of iron , manganese and cobalt by atomic absorption spectrophotometer according to Chapman and Pratt (1961).Total soluble carbohydrates and soluble sugars expressed as glucose were determined according to the methods of Smith *et al.*(1956).Insoluble sugars contents were calculated by the differences between contents of total carbohydrates and soluble carbohydrates.

Simple correlation coefficients (r) between applied micronutrients treatment and any of corn plant organs, micronutrients uptake and carbohydrate fractions content was conducted. Multiple regression equations and multiple correlation coefficients (R) between multiple micronutrients concentration and the different organs of corn plant, micronutrients uptake and carbohydrate fractions content were calculated.

RESULTS AND DISCUSSION

Dry matter production:-

Data illustrated in Table (2) elucidate the effect of foliar application of Fe, Mn and Co and their combinations on biomass of corn plants. Application of different rates of Fe, Mn and Co individually or in combination with them ,generally, increased the dry matter yield of different plant organs more than the control treatment .However, data reveal that , application Fe3, Mn3 and combination of both elements(R2) decreased the dry matter yield of leaves ,stem ,root and total dry weight of corn plants in spite of the relatively high value recorded for leaves and stems at the moderate rate of Mn2 (200 mg/L Mn) treatment. An opposite trend was encountered with Co treatments, which increased the dry matter yield of leaves, root and total dry matter for corn plant with increasing Co concentration. This is true, in spite of the relatively decreased stem dry matter due to increased cobalt concentration. These results are in agreement with those of Mengel (1995) and Briat and Lobreaux (1997) who found that dry matter production of corn was improved with Fe supplied to plants. However, Li, *et al.*, (2001) and Olaleye *et al.*, (2001) added that dry matter yield was decreased with increasing Fe^{2+} concentration in rice plant and shoots was most sensitive to differences in tolerating excessive Fe^{2+} concentration (Fageria and Rabelo,1987). Plant great tolerance to excess Mn was associated with restricted absorption , restricted translocation of excesses Mn to the shoots ,or great tolerance to high Mn levels within the plant tissue (El-Jaoual and Cox ,1998). In addition, Marschner (1995) reported that cobalt indirectly associates with several enzymes and coenzymes therefore, growth and metabolism of plants depending on its availability in growing medium. Agarwala *et al.* (1977) added that Co^{2+} was found to be least effective in causing phytotoxic effects.

Generally, the combined application of Fe +Co ,Mn+Co and Fe+Mn+Co show a positive effect on dry matter yield of different organs compared with addition individually. of (Fe & Mn) , Also , increasing or decreasing the dry matter yield was related to the rate of added elements and combined treatment. Data also revealed that application of Mn+Co was the most effective in increasing the dry matter production .

Table (2): Dry matter production of corn plant (g/plant)as affected by iron, manganese, cobalt and their combination treatments

Treatments	Rate of application	Leaves	stem	root	Total plant
Control		13.0	11.6	16.4	41.0
Fe	Fe1	15.2	14.8	23.2	53.2
	Fe2	13.1	13.7	18.9	45.6
	Fe3	12.0	13.8	10.4	36.2
Mn	Mn1	12.9	13.9	33.3	60.1
	Mn2	13.3	16.2	20.0	49.5
	Mn3	12.5	14.1	19.1	45.7
Co	Co1	11.5	13.1	17.7	42.3
	Co2	12.7	13.0	28.4	54.1
	Co3	15.3	12.7	37.0	65.0
Fe+Mn	FeMnR1	14.7	18.6	40.3	73.6
	FeMnR2	13.6	17.2	11.1	41.8
Fe+Co	FeCoR1	12.3	15.8	18.0	46.1
	FeCoR2	13.8	19.2	24.0	57.0
Mn+Co	MnCoR1	12.9	14.8	33.4	61.1
	MnCoR2	14.4	16.6	47.3	78.0
Fe+Mn+Co	(FeMnCo)1	13.4	14.4	25.8	53.6
	(FeMnCo)2	15.0	16.1	30.6	61.6
LSD at 0.05 for					
Treatments (A)		0.36	0.60	0.98	1.12
Rate (B)		0.27	0.45	0.80	0.82
(A)*(B)		0.72	1.20	2.13	5.32

However, simple correlation coefficients (r) between any of paired applied micronutrients concentration and dry weight for different organs of corn plant are shown in Table (3). It was cleared that there were a positive significant correlation between Co treatment and leaves, root and total plant dry weight. Fe application gave a positive significant correlation with leaves, root and total plant dry weight. No significant relation was cleared between Mn treatments and different organs dry weight of corn plant except stem weight, which gave a positive correlation 0.274* only. This is may due to the sufficient initial available Mn quantity in soil (Table 1).

On the other hand, multiple regression equations and multiple correlation coefficients (R) between combined micronutrients and dry weight for different organs of corn plant are shown in Table (4). Obtained calculations indicated that all double and triple interactions were significant for root and total plant dry weight. Leaves dry weight showed significant relations in all interaction treatments except for Fe + Mn interaction, where stem dry weight showed significant relations for Fe+Mn and Fe+Mn+Co interaction only.

Table (3): Simple correlation coefficient (r) between applied concentration micronutrients and dry weight for different corn plant organs

Plant parts	Foliar treatments		
	Fe	Mn	Co
Leaves	-0.005_{NS}	0.073_{NS}	0.378**
Stem	0.276*	0.274*	-0.021_{NS}
Root	-0.442**	0.101_{NS}	0.507**
Total	-0.339*	0.146_{NS}	0.480**

** significant at .01 level * significant at .05 level NS non-significant

Table (4): Multiple regression equations and correlations multiple coefficients (R) between combined application of micronutrients (mg/L), and dry weight (g/plant) for different organs of corn plant

Plant parts	Regression equation	R
	Fe+Mn	
Leaves		0.071_{NS}
Stem	13.9+0.00629(Fe)+0.00622(Mn)	0.43**
Root	28.6-0.0394(Fe)+0.0020(Mn)	0.44**
Total	55.8-0.0330(Fe)+0.0090(Mn)	0.35*
	Fe+Co	
Leaves	13.0+0.00073(Fe)+0.0161(Co)	0.385*
Stem		0.277_{NS}
Root	24.6-0.0321(Fe)+0.157(Co)	0.616**
Total	52.1-0.0261(Fe)+0.176(Co)	0.541**
	Mn+Co	
Leaves	12.9+0.00148(Mn)+0.0166(Co)	0.404*
Stem		0.276_{NS}
Root	19.4+0.0177(Mn)+0.195(Co)	0.542**
Total	46.8+0.0244(Mn)+0.214(Co)	0.535**
	Fe+Mn+Co	
Leaves	12.8+0.00112(Fe)+0.000173(Mn)+0.0177(Co)	0.42*
Stem	13.6+0.00679(Fe)+0.00668(Mn)+0.00849(Co)	0.44*
Root	23.2-0.0296(Fe)+0.0112(Mn)+0.167(Co)	0.63**
Total	49.6-0.0217(Fe)+0.0196 (Mn)+0.194(Co)	0.57**

** significant at .01 level *significant at .05 level NS non-significant

Fe- distribution through corn plant organs:

Data presented in Table (5) show the Fe uptake by different plant organs (leaves, stem and root) of the studied corn plant. Data reveal that the addition of all the studied micronutrients (Fe, Mn and Co), generally, increased Fe uptake as compared to control treatment in different plant organs. Such results were noted when these treatments applied individually or in combination. Also, iron was accumulated in root as compared to leaves and stem . Similar results were obtained by (Agarwala e al., 1977) who found that both Fe uptake and transport between plant organs are highly affected by several plant and environmental factors such as ratios of several heavy metals, which are most pronounced. Also, El-Jaoual and Cox (998) added that the most pronounced symptom is the ratio of Fe to other elements and heavy metals in particular. The proper Fe/Mn ratio seems to be the most obligatory factor in the tolerance of plants to Fe toxicity.

Table (5): Iron uptake by corn plant (mg/plant)as affected by iron,manganese , cobalt and their combination treatments.

Treatments	Rate of application	Leaves	stem	root	Total plant
Control		2.01	2.05	6.15	10.2
Fe	Fe1	3.25	2.35	8.72	14.3
	Fe2	2.83	2.48	7.51	12.8
	Fe3	2.63	3.05	4.58	10.2
Mn	Mn1	2.62	1.93	11.4	16.0
	Mn2	2.63	2.64	7.74	13.0
	Mn3	2.39	2.28	6.79	11.5
Co	Co1	1.94	2.64	6.82	11.4
	Co2	2.08	2.18	9.44	13.7
	Co3	2.51	1.77	11.2	15.5
Fe+Mn	FeMnR1	2.88	2.90	14.2	19.9
	FeMnR2	2.74	2.28	3.72	8.74
Fe+Co	FeCoR1	2.35	2.13	5.87	10.4
	FeCoR2	2.43	2.46	7.30	12.2
Mn+Co	MnCoR1	2.42	2.18	11.2	15.8
	MnCoR2	2.39	2.10	13.4	17.9
Fe+Mn+Co	(FeMnCo)1	2.51	1.81	7.97	12.3
	(FeMnCo)2	2.70	2.02	9.36	14.1
LSD at 0.05 for					
Treatments (A)		0.32	0.46	0.43	0.51
Rate (B)		0.17	0.42	0.29	0.49
(A)*(B)		0.44	0.50	0.79	1.02

Results also show that values of Fe uptake by leaves and roots were decreased as a result of Fe2 ,Fe3 and Mn3 application by leaves and root . These results may be due to the high rates of Fe and Mn which were more toxic to leaves and roots than stem. In this connection, Fageria and Reblo, (1987) stated that nutrient uptake inhibition under different concentrations of iron which, in turn decreased iron uptake and plant growth.

An opposite trend was recorded in Fe uptake by leaves and root as a result of Co application mainly due to Co helps to Fe accumulation in both leaves and roots.

As far as the combined interactions between the studied micronutrients (Fe + Mn), (Fe + Co) and (Fe + Mn + Co) obtained data, generally, reveal that slightly increased or no significant effect on both leaves and/or stem as compared to control treatment; accumulation of Fe was noted in roots as affected of all interaction treatments..

Furthermore, application of both (FeMnR2) and (MnCoR2) at high rate decreased Fe uptake by plant organs (leaves and stem). Similar trend was obtained in root when (FeMnR2) was applied at high rate. In this connect, Fageria *et al* (1990) reported that addition of MnO_2 led to an increase in the redox potential and reduced uptake of Fe and organic reduction products. However, exposure to excess concentration of the heavy metals decreased the uptake of Fe and its translocation to leaves along with influencing the activity of iron enzymes (Agarwala *et al.*, 1977 and Pandey and Sharma, 2002).

An opposite trend was obtained when (Fe +Co) and (Fe + Mn + Co) treatments were applied; high rates caused an Fe to be accumulated in different plant organs (leaves, stem and root).

Generally, Fe was accumulated in root more than either leaves or stem as a result of studied interaction treatments. These results are in agreement with Chatterjee and Chatterjee (2003) who reported that addition of Fe along with excess Co ameliorated the effect of excess Co by partially increasing the biomass and iron uptake in tomato plants.

The calculation simple correlation coefficients (r) between applied (Fe,Mn and Co) and Fe uptake in all plant organs are non significant except for Fe treatment of leaves and Mn treatment for root , simple correlation coefficient (r) are 0.37** and 0.421**, respectively.

On the other hand, regression equation and multiple correlation coefficients (R) between combined applications of micronutrients treatments and Fe uptake for different organs of corn plants are shown in Table (6). Obtained calculations indicate that the relations for all double and triple treatment interactions were positively significant for Fe uptake by roots and total plant. Double interaction (Mn + Co) treatment was an exception for total plant. However, leaves and stem were also with positive significant interaction for (Fe + Co) and (Fe + Mn + Co) treatments; interaction for the treatment (Mn + Co) was positively significant for stem only.

Excess Mn can affect unfavorably the Fe action in tissues, catalyzing the oxidation of the physiologically active Fe^{2+} to the inactive Fe^{3+} from (El-Jaoual and Cox, 1998).

Mn distribution through corn plant organs:

Data in Table (7) illustrate the Mn uptake by different corn plant organs (leaves, stem and root). Results reveal that applied Fe,Mn and Co treatments either individually or in combination,generally, increased Mn uptake as compared to control treatment; root accumulated high rate of Mn as compared to leaves or stem.

Foliar application with Fe and /or Mn individually to corn plants decreased Mn uptake by total plant and different organs (leaves, stem and root) ,except with high rate of Mn(Mn3) on leaves . Uptake of Mn decreased as rates of Fe and Mn increased. This is mainly attributed to the mutual strong antagonistic relationship between (Fe and Mn). Also, Mn was accumulated in root as compared to leaves or stem . Addition of high rates of Mn(Mn3), on the other hand, elevated the accumulation of Mn in leaves . These results may due to great Mn tolerance associated with restricted absorption and/or restricted translocation of excess Mn to the shoots , or great tolerance to high Mn levels within the plant tissue (El-Jaoual and

Cox,1998). Also,Galvez *et al.*(1989) reported that growth restriction of sorghum plants was noticed with grown in the nutrient solution with high levels of Mn .When growth restriction occurs ,it is usually more severe in the roots than in the shoots (Mortley ,1993).Also , Benac (1976) added that the superior Mn tolerance of corn was associated with reduced translocation of Mn from the roots and stems to the leaves.

On the contrary, Mn uptake by leaves and root increased significantly by increasing Co application. While Mn-uptake by stem decreased insignificantly. In this connection , Dahdoh and Moussa (2000) found that addition of Co increased significantly Mn uptake in broad bean and peanut plants.

Table(6): Multiple regression equations and multiple correlations coefficients (R) between combined application of micronutrients (mg/L)and Fe uptake (mg/plant) for different organs of corn plant

Plant parts	Regression equation	R
	Fe+Mn	
Leaves		0.31 NS
Stem		0.27 NS
Root	96.5-0.119(Fe)-0.0078(Mn)	0.46**
Total	143-0.0960(Fe)-0.0094(Mn)	0.37*
	Fe+Co	
Leaves	25.6+0.00846(Fe)-0.0359(Co)	0.402*
Stem	23.7+0.00963(Fe)-0.0616(Co)	0.409**
Root	88.4-0.104(Fe)0.273(Co)	0.527**
Total	138-0.0858(Fe)+0.176(Co)	0.402*
	Mn+Co	
Leaves		0.329 NS
Stem	25.6-0.00817(Mn)-0.0749(Co)	0.397*
Root	74,3+0.0301(Mn)+0.376(Co)	0.365*
Total		0.247 NS
	Fe+Mn+Co	
Leaves	25.7+0.00824(Fe)-0.00099(Mn)-0.0368(Co)	0.40*
Stem	24.5+0.00821(Fe)-0.00636(Mn)-0.0673(Co)	0.43*
Root	87.5-0.0102(Fe)+0.0076(Mn)-0.0280 (Co)	0.53*
Total	138-0.0857(Fe)-0.0003(Mn)+0.176 (Co)	0.40*

** significant at .01 level *significant at .05 level NS non-significant

The combined treatment (Fe+Mn) showed negative effect on Mn uptake by leaves stem and root, especially at high rate (FeMnR2). Obtained data agreed with Kohno and Foy (1983) who found that high concentrations of Fe decreased the absorption of Mn by some plants. Also, Bachman and Miller (1995) found that 1 to 60 mg/kg Fe in the medium caused Fe/Mn toxicity in "Aurora" geranium plants.

Table (7): Manganese uptake by corn plant (mg/plant)as affected by iron, manganese , cobalt and their combination treatments

Treatments	Rate of application	Leaves	stem	root	Total plant
Control		1.44	0.77	3.14	5.35
Fe	Fe1	1.80	1.11	5.83	8.74
	Fe2	1.54	1.01	5.34	7.89
	Fe3	1.37	0.98	2.57	4.92
Mn	Mn1	1.93	1.12	9.14	12.2
	Mn2	2.36	1.23	6.44	10.0
	Mn3	3.78	0.95	6.76	11.49
Co	Co1	1.37	1.20	5.45	8.02
	Co2	1.42	1.17	6.92	9.51
	Co3	1.65	1.11	7.83	10.6
Fe+Mn	FeMnR1	2.00	1.42	8.27	11.69
	FeMnR2	1.65	1.03	2.86	5.54
Fe+Co	FeCoR1	1.51	1.13	5.52	8.20
	FeCoR2	1.67	1.18	5.56	8.37
Mn+Co	MnCoR1	2.00	1.01	10.62	13.6
	MnCoR2	1.69	1.04	14.27	17.0
Fe+Mn+Co	(FeMnCo)1	1.82	0.98	8.08	10.9
	(FeMnCo)2	1.77	1.06	8.51	11.3
LSD at 0.05 for					
Treatments (A)		0.48	0.16	1.15	1.29
Rate (B)		0.24	0.09	0.83	2.01
(A)*(B)		0.63	0.23	2.20	2.14

Similar trend was obtained for leaves only when (Mn+Co) and (Fe+Mn+Co) treatments were applied with high rates .Heavy metal ions accumulated in different parts of the plant after they absorbed by the root system in retardation of plant growth .This could due to their interference with the activities of number of enzymes essential for normal metabolism and development processes.

On the other hand, high rates of (FeCoR2) , (MnCoR2) and (FeMnCoR2) were caused an accumulation of Mn in both stem and total corn plant .Interaction of the studied minerals Fe,Mn and Co in the growing medium has been experienced to change the cobalt status of several plant species (Dekock,1956 and Patel *et al.*,1976).Also, interference of heavy metals including cobalt with iron in plant metabolism is known to induce disturbances creating physiological iron deficiency (Samarkoon and Rauser,1979).

Simple correlation coefficients (r) between micronutrients application and Mn uptake of different plant organs are non significant except for Mn treatment of leaves and root , (r) values are 0.333* and 0.305* ,respectively.

Furthermore, regression equations and multiple correlation coefficient (R) between combined applications of micronutrients and Mn uptake for total plant and different plant organs (leaves ,stem and root)are shown in Table (8). Results reveal that the relations for all interactions treatment and Mn uptake were in positive significant trend for root and total plant .However, double interaction between each of Fe,Mn and Co was significant for leaves as well as for triple interaction treatment between (Fe,Mn and Co) was not positively significant for either leaves or stem.

From above mentioned data it could be noticed that (Mn+Co) treatments ,generally, had a positive significant effect on Mn uptake by different plant organs and /or total plant.

Table (8) : Multiple Regression equations and multiple correlation coefficient (R) between combined application of micronutrients and Mn uptake (mg /plant) of corn plant

Plant parts	Regression equation	R
	Fe+Mn	
Leaves	1.58-0.000862(Fe)+0.00374(Mn)	0.682**
Stem		0.089 NS
Root	7.31-0.0113(Fe)+0.00605(Mn)	0.508**
Total	10.0-0.0125(Fe)+0.00988(Mn)	0.579**
	Fe+Co	
Leaves	2.14-0.00186(Fe)-0.00669(Co)	0.382*
Stem		0.089 NS
Root	7.09-0.0108(Fe)+0.0108(Co)	0.541**
Total	10.4-0.0130(Fe)+0.0255(Co)	0.522**
	Mn+Co	
Leaves	1.55+0.00379(Mn)-0.00252(Co)	0.675**
Stem	1.11+0.000163(Mn)+0.00057(Co)	0.55*
Root	4.89+0.0102(Mn)+0.0477(Co)	0.527**
Total	7.55+0.0141(Mn)+0.0458(Co)	0.556**
	Fe+Mn+Co	
Leaves		0.70 NS
Stem		0.09 NS
Root	6.05-0.00898(Fe)+0.00821(Mn)+0.0393(Co)	0.62**
Total	8.88-0.0104(Fe)+0.0119(Mn)+0.0361(Co)	0.65**

Cobalt distribution through corn plant organs.

Data in Table(9) show that foliar application of Fe,Mn and Co individually and /or combined with them to corn plants ,generally , increased Co uptake by different plant organs as compared to control treatment . Data also reveal that Co uptake by root was accumulated in a significant positive trend in root as a result of applied tested treatments. Also, leaves accumulated high values of Co uptake than stem.

On the other hand, high rates of Fe and Mn either individually or combined with them,generally, decreased Co uptake by total plant and root. An opposite trend was obtained for stem and leaves in spite of high rate of Mn (Mn3) had reduced Co uptake by leaves and stem.

As expected ,foliar addition of Co to corn plants increased Co uptake by different organs .The increases were more evident in root compared to stem and/or leaves .These results agreed with Chatterjee and Chatterjee (2003) who reported that excess Co had to increase the concentration of Co in different plant parts.The maximum concentration of Co was noticed in roots while minimum one was in fruits .Also, Agawala (1977) stated that Co^{2+} was found to be least effective in causing phytotoxic effects.

Likewise, foliar application of different rates of (Fe+Co) , (Mn+Co) and (Fe+Mn+Co) ,generally , increased significantly the uptake of cobalt by different plant organs. These increases were markedly as a result of applied high rates of the studied heavy metals. In this concern, Chatterjee and Chatterjee(2003) found that addition of Fe along with excess Co ameliorated the effect of excess Co by partially increasing the biomass ,iron and elevated the accumulation of carbohydrates .Furthermore, the presence of variable concentrations of micronutrients in the growing medium has been experienced to change the cobalt status of several plant species (Dekock,1956 and Patel *et al.*,1976) .

Table (9): Cobalt uptake by corn plant (mg/ plant)as affected by iron, Manganese, cobalt and their combination treatments

Treatments	Rate of application	Leaves	stem	root	Total plant
Control		0.06	0.03	0.167	0.26
Fe	Fe1	0.09	0.03	0.24	0.36
	Fe2	0.07	0.03	0.21	0.31
	Fe3	0.07	0.05	0.14	0.25
Mn	Mn1	0.04	0.06	0.36	0.46
	Mn2	0.12	0.07	0.23	0.42
	Mn3	0.08	0.03	0.24	0.35
Co	Co1	0.09	0.03	0.21	0.33
	Co2	0.28	0.04	0.48	0.80
	Co3	0.40	0.06	0.62	1.08
Fe+Mn	FeMnR1	0.12	0.09	0.37	0.58
	FeMnR2	0.13	0.10	0.12	0.35
Fe+Cc	FeCoR1	0.13	0.05	0.27	0.45
	FeCoR2	0.19	0.14	0.25	0.58
Mn+Co	MnCoR1	0.11	0.06	0.40	0.57
	MnCoR2	0.12	0.45	0.50	1.07
Fe+Mn+Co	(FeMnCo)1	0.15	0.03	0.26	0.44
	(FeMnCo)2	0.14	0.06	0.33	0.53
LSD at 0.05 for					
Treatments (A)		0.046	0.032	0.056	0.089
Rate (B)		0.020	0.020	0.028	0.302
(A)*(B)		0.053	0.053	0.078	0.061

Table (10) show simple correlation coefficients (r) between Co – uptake and micronutrients application treatments of different organs of corn plant.

Table (10): Simple correlation coefficient (r) between applied micronutrient and Co-uptake for different organs of corn plant

Plant parts	Foliar treatments		
	Fe	Mn	Co
Leaves	-0.59**	-0.34*	0.79**
Stem	-0.31*	0.34*	0.24NS
Root	-0.44**	-0.3*	0.19 NS
Total	-0.44**	-0.33*	0.36**

** significant at .01 level * significant at .05 level NS non-significant

Obtained calculations indicated that cobalt uptake was negatively response to applied studied heavy metal (Fe,Mn and Co) treatments. Also, cobalt uptake highly positive significant for leaves and total plant as a result of applied cobalt treatments.

Regression equations and multiple correlation coefficients(R) between combined rates of the applied micronutrients and Co- uptake are shown in Table (11) . Calculated data indicated that (Fe+Mn) treatment was not significant for either total plant or different plant organs ,such results were recorded for stem and root when (Fe+Co) was applied. Again, indicated data reveal that the relation of all combined treatments and Co uptake were not significant for root.

Table(11): Multiple Regression equations and multiple correlation coefficient (R) between combined application of micronutrients (mg/L) and Co uptake (mg/plant) for different organs of corn plant

Plant parts	Regression equation	R
	Fe+Mn	
Leaves		0.303 NS
Stem		0.305 NS
Root		0.205 NS
Total		0.212 NS
	Fe+Co	
Leaves	0.0792-0.000039(Fe)+0.00258(Co)	0.809**
Stem		0.226 NS
Root		0.315 NS
Total	0.486-0.000850(Fe)+0.00896(Co)	0.405**
	Mn+Co	
Leaves	0.0785-0.000033(Mn)+0.00259(Co)	0.809**
Stem	0.0455+0.000056(Mn)+0.000158(Co)	0.302**
Root		0.329 NS
Total	0.288+0.00105(Mn)+0.0104(Co)	0.417**
	Fe+Mn+Co	
Leaves	0.0848-0.000049(Fe)-0.000043(Mn)+ 0.00254(Co)	0.81**
Stem	0.0387+0.000053(Fe)+0.00068(Mn)+0.000207(Co	0.39*
Root		0.34 NS
Total	0.371-0.000647(Fe)+0.000907(Mn)0.00977(Co)	0.43*

Translocation of Fe,Mn and Co:-

The application different rates of studied heavy metals either individually or combined with each others had affected their translocation between corn plant organs. Simple correlation coefficients (r) between Fe,Mn and Co application and their translocation (Table ,12) suggested that high positive significant effect between Fe and /or Co treatments and their translocation within different plant organs ,opposite trend was observed for Mn translocation and tested treatments.

Table(12):Simple correlation coefficient (r) between applied concentration of micronutrients and their translocation through corn plant

Treatments	Translocation		
	Fe	Mn	Co
Fe	0.60**	0.0_{NS}	-0.44**
Mn	0.474**	0.071_{NS}	-0.45**
Co	0.40**	0.063_{NS}	-0.044_{NS}

** significant at .01 level * significant at .05 level NS non-significant

Finally, regression equations and multiple correlation coefficient (R) (Table ,13) indicated that translocation of Fe,Mn and Co under both double and triple interactions treatments were high significant in corn plant. This is true in spite of there was no significant effect for Co translocation under (Mn+Co) interaction treatments.

Table(13): Multiple regression equations and multiple correlation coefficient (R) between combined application of micronutrient (mg/L) and micronutrient translocation for different organs of corn plant

Element	Regression equation	R
	Fe+Mn	
Fe	48.4+0.162(Fe)+0.0255(Mn)	0.61**
Mn	38.1+0.114(Fe)+0.0358(Mn)	0.50**
Co	49.0+0.145(Fe)+0.0461(Mn)	0.42**
	Fe+Co	
Fe	60.5+0.140(Fe)-0.355(Co)	0.69**
Mn	50.8+0.0907(Fe)-90.341(Co)	0.60**
Co	52.3+0.139(Fe)+0.052(Co)	0.40*
	Mn+Co	
Fe	77.8-0.247(Mn)-0.653(Co)	0.45**
Mn	60.8-0.0029(Mn)-0.413(Co)	0.46**
Co		0.07_{NS}
	Fe+Mn+Co	
Fe	59.7+0.141(Fe)+0.0063(Mn)-0.350(Co)	0.69**
Mn	48.6+0.0947(Fe)+0.0180(Mn)-0.325(Co)	0.61**
Co	45.8+0.150(Fe)+0.0514(Mn)+0.098(Co)	0.43*

From above mentioned data it could be reported that applied Fe,Mn and Co individually or combined with them had affected their translocation through different plant organs (leaves, stems and roots).

Distribution of carbohydrate fractions:-

Table (14) represents the total carbohydrates (TC), soluble carbohydrates (SC) and insoluble carbohydrates(ISC) of different plant organs (leaves, stem and root) of the studied corn plant. Results show that values of both TC and ISC were frequently increased significantly in the studied plant parts by application of Fe, Mn and Co either individually or in combination with them as compared to control treatment, responses being dependent on the concerned plant part. An opposite trend was encountered with soluble carbohydrates (SC) which decreased as a result of applied tested treatments.

Obtained data agreed with the findings obtained by Rauser (1978) and Rauser and Samarkoon (1980) who found that exposure of bean seedlings to heavy metals was responsible for accumulation of carbohydrates in fully expanded leaves and was due to more photo- assimilate exports via vein loading. Also, Khan *et al.*(2000)added that carbohydrates concentration was higher in shoots and roots in corn plant as response to Mn treatment.

With respect to Fe applied individually with different rates ,data clear that TS,SC and ISC decreased in both leaves and stem as Fe rate increased ; the opposite is true for root which accumulated carbohydrate fractions(TC,SC and ISC) with high rate of Fe(Fe3) .

Also, values of TC and ISC were decreased in leaves and stem as Mn treatments increased as well as relatively different trend was obtained with soluble carbohydrate, which increased in both leaves and stem than root. In this connection, Khan *et al.*,(2000) reported that total carbohydrate were higher in roots than shoots in corn plant as affected to Mn treatment.

On the other hand , foliar application of Co with different rates increased significantly the TC,SC and ISC in both leaves and stem along with root. Similar findings were reported by Rauser (1978) and Rauser and Samarkoon (1980).This increase might be due to more photo assimilate exports via vein loading resulting in an elevation of carbohydrates in excess metal exposed leaves(Chatterjee and Chatterjee ,2003) .

The combined treatments (Fe+Mn), (Fe+Co) and (Fe+Mn+Co) decreased significantly carbohydrates fractions (TC,SC and ISC) .The high rate of such combinations were not favorable as compared to relatively low rates for different plant organs. On the contrary ,high rate of (Mn+Co) treatment caused an accumulation of (TC,SC and ISC) in root.

Again, it may be worth to mention that carbohydrate fractions (TC,SC and ISC)distribution between plant organs (leaves, stem and root) were generally superior for leaves and stem under all treatments as compared to the same content in root .

Furthermore, simple correlation coefficients(r) between applied micronutrients and carbohydrate fractions for different plant organs of corn plant are shown in Table (15).Data clear that Fe treatments had no-significant correlation for all plant parts of corn except for soluble carbohydrate for leaves. Mn treatment ,also, gave no-significant effect for TC,ISC in leaves, ISC in stem and SC in root. However, Co treatments were high significantly for leaves and SC for stem; root exhibited no significant response for SC only.

Table(14): Effect of iron, manganese and cobalt treatments on the contents (mg/g) of total carbohydrate, soluble carbohydrate and insoluble carbohydrate in different plant organs of corn plant

Treat.	Rate	Leaves			Stem			Root		
		TC*	SC**	ICS***	TC*	SC**	ICS***	TC*	SC**	ICS***
Control		348	85.0	263	296	87.7	383	373	36.4	337
Fe	Fe1	439	95.2	344	661	95.2	566	372	39.8	329
	Fe2	370	95.8	274	529	95.8	433	428	38.2	393
	Fe3	339	77.6	361	448	77.6	370	439	43.1	403
Mn	Mn1	422	70.0	352	521	70.0	451	405	39.8	373
	Mn2	358	79.1	379	460	79.1	381	445	36.2	408
	Mn3	354	82.3	382	445	82.3	373	509	35.9	475
Co	Co1	430	72.0	358	430	72.0	358	417	37.0	373
	Co2	492	74.8	417	492	74.8	417	487	44.1	457
	Co3	493	72.7	420	493	72.5	420	428	36.1	398
Fe+Mn	FeMnR1	435	81.9	353	435	81.9	353	365	37.8	321
	FeMnR2	424	78.6	345	424	78.6	345	341	37.4	304
Fe+Co	FeCoR1	485	81.5	404	490	81.5	409	462	47.8	413
	FeCoR2	463	70.8	392	463	70.8	392	412	38.5	369
Mn+Co	MnCoR1	494	66.2	428	494	66.2	428	405	39.6	364
Fe+Mn+Co	(FeMnCo)1	460	69.9	390	461	69.9	391	469	38.7	435
	(FeMnCo)2	410	64.8	345	410	64.8	345	441	38.1	391
Mean for rate	R1	383	82.5	315	471	84.0	387	384	37.5	346
	R2	442	78.5	364	480	78.5	402	438	40.3	398
	R3	445	70.1	379	450	70.9	379	628	40.0	391
LSDat 0.05 For:-										
Treatments (A)		15.0	5.32	24.4	17.9	1.67	17.6	15.9	2.67	10.4
Rate (B)		8.53	2.12	13.1	6.25	0.41	6.25	9.50	1.37	7.89
(A)* (B)		13.0	5.61	34.7	16.6	1.08	16.5	13.4	3.61	20.9

*** Total carbohydrate **Soluble carbohydrate *** insoluble carbohydrate**

Table(15): Simple correlation coefficient (r) between concentration of micronutrients treatments and carbohydrate fraction in different organs of corn plant

Plant parts	Carbohydrate fractions	Foliar treatments		
		Fe	Mn	Co
Leaves	Total	-114 NS	- 0.60 NS	0.575**
	Soluble	224*	- 0.365**	- 0.498**
	Insoluble	111 NS	0.017 NS	0.620**
Stem	Total	109 NS	- 0.286*	0.006 NS
	Soluble	216 NS	- 0.395**	- 0.522*
	Insoluble	152 NS	- 0.224 NS	0.102 NS
Root	Total	171 NS	0.292*	0.301*
	Soluble	0.48 NS	- 0.127 NS	0.168 NS
	Insoluble	- 0.180 NS	0.312*	0.292*

**** significant at .01 level * significant at .05 level NS non-significant**

On the other hand, regression equations and multiply correlation coefficients(R) between combined rate of micronutrients application and carbohydrate fractions for different organs of corn plants are shown in Table (16). Obtained relations showed that all double and triple treatment interactions and carbohydrate fraction were significant positively for leaves along with SC ,which was only positively significant for stem. Also double interaction (Fe=Mn) ,(Fe+Co) and (Mn+Co) were positively significant for root, FeMnCo treatment gave significant positive for TC in root.

Finally leave of corn plant showed high significant number of various carbohydrate fractions than stem and /or root ,such data clear that the important of leaves in distribution and accumulation of carbohydrate in plant.

Table (16). Regression equations and multiple correlation coefficient I between combined application of micronutrient treatments (ppm), and carbohydrate fraction in different organs of corn plant.

Plant parts	Carbohydrate fraction	Regression equation	R
		Fe+Mn	
Leaves	Total	445-0.0512{Fe}-0.0328{Mn}	0.14**
	Soluble	77.5+0.0141{Fe}-0.0311{Mn}	0.42**
	in soluble		0.01 NS
Stem	Total		0.33 NS
	Soluble	77.7+0.0130 (Fe)-0.0130 (Mn)	0.42**
	insoluble		0.30 NS
Root	Total		0.32 NS
	Soluble		0.13 NS
	In –soluble	381- 0.0554 (Fe)+0.124 (Mn)	0.34*
		Fe+Co	
Leaves	Total	418-0.0009(Fe)+0.916(Co)	0.57**
	Soluble	78.6+0.0117(Fe)-0.166(Co)	0.51**
	insoluble	334+0.0043(Fe)+1.15(Co)	0.62**
Stem	Total		0.11 NS
	Soluble	79.0- 0.0103 (Fe)- 0.172 (Co)	0.53**
	insoluble		0.17 NS
Root	Total	421- 0.0519 (Fe)+ 0.494 (Co)	0.32*
	Soluble		0.19 NS
	insoluble	382- 0.0554 (Fe)+0.463 (Co)	0.32*
		Mn+Co	
Leaves	Total	416+0.0178(Mn)+0.930(Co)	0.58**
	Soluble		
	insoluble	328+0.0611(Mn)+1.19(Co)	0.63**
Stem	Total	484-0.143(Mn)-0.092(Co)	0.29*
	Soluble	84.6-0.0434(Mn)-0212(Co)	0.72*
	insoluble		0.23 NS
Root	Total	399+0.158(Mn)+0.648(Co)	0.46**
	Soluble		0.19 NS
	insoluble	359+0.162(Mn)+0.622(Co)	0.47**
		Fe+Mn+Co	
Leaves	Total	415+0.0032(Fe)+0.0185(Mn)+0.933(Co)	0.58**
	Soluble	84.0+0.00222(Fe)-0.0423(Mn)-0.204(Co)	0.69**
	insoluble	326+.0189 (Fe)+0.0652 (Mn)+1.21 (Co)	0.64**
Stem	Total		0.34 NS
	Soluble	84.5+.00068(Fe)-0.0433(Mn)-0.211(Co)	0.72**
	insoluble		0.30 NS
Root	Total	401-0.0175 (Fe)+0.0.154(Mn)+0.631(Co)	0.46**
	Soluble		0.20 NS
	in soluble		047 NS

** significant at .01 level   * significant at .05 level   NS non-significant

Conclusions

From the previous results, It was concluded that foliar application of Fe and Mn with high rates generally decreased dry matter production of different corn plant organs ; Co treatments were an opposite trend. However , Fe ,Mn and Co uptake by different organs increased as a result of applied high concentrations .Also ,treated corn plant with Fe, Mn and Co individually and /or combined with them ,generally, were positive effect on carbohydrate fractions distribution through corn plant as compared to un-treated plants.The high rates of combined treatments were hazardous for all carbohydrate fraction. These data need more investigations on many species of other crops and different rates of these elements especially Co to justify the effect of Co whether added individually or in combination with different minerals on plant growth and elemental composition.

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امتصاص الحديد والمنجنيز والكوبلت بواسطة نبات الزرة وتوزيع الكربوهيدرات خلال اجزائة

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أجريت تجربة لدراسة أستجابة نبات الذرة للرش بكل من الحديد Fe والمنجنيزMn وذلك بتركيزات ١٠٠،٢٠٠،٤٠٠ ملليجرام/ لتر والكوبلت Co بمعدل ٢٥،٥٠،١٠٠ملليجرام/ لتر ، وكذلك التفاعل بين (Mn+Fe)، (Co+Fe)، (Co+Mn)، (Co+Mn+Fe) حيث تم أضافة هذه المخاليط بمعدلين من العناصر المختبرة.

اشارت النتائج الى ان الأضافات المختلفة من كل من الحديدوالمنجنيز Fe, Mn, قد ادت الى .زيادة وزن المادة الجافة للاوراق والسيقان والجذور والوزن الجاف الكلى لنبات الذرة بالمقارنةبمعاملة الكنترول. وقد أحدثت المعاملة بالتركيزات العالية من الكوبلت تأثيرا مشابها. أيضا المعاملة بمخاليط العناصر أدت الى زيادة أنتاج المادة الجافة لكل أجزاء النبات بالرغم من التاثير العكسى عند اضافة مخلوط الحديد والمنجنيز Mn+Fe

اظهرت النتائج الى زيادة امتصاص كل من الحديد والمنجنيز والكوبلت فى اجزاء النبات المختلفة عند المعاملة بالحديد والمنجنيز والكوبلت سواء بصورة منفردة او عند استخدامها فى صورة مخاليط بالمعدلات المختلفة وذلك بالمقارنة بالكونترول.كما ادت هذه المعاملات الى تراكم هذه العباصر فى الجذر بالمقارنة بالساق والاوراق.

أدت اضافة التركيزات العالية من الحديد والمنجنيز سواء بصورة منفردة او فى صورة مخاليط الى نقص امتصاص الحديد فى كل من الاوراق والجذر وكان العكس صحيحا عند اضافة الكوبلت بمعدلاته المختلفة .وكانت التركيزات العالية من المخاليط لكل من (Fe+Mn),(Fe+Co),(Fe+Mn+Co) ذات تاثير ايجابى على امتصاص الحديد بواسطة الجذور بالمقارنة للاوراق والساق

بصفة عامة يقل امتصاص المنجنيز بواسطة النبات الكلى وكذلك اعضاءه المختلفة نتيجة اضافة التركيزات العالية لكل من الحديد والمنجنيز وكان العكس صحيحا عند اضافة الكوبلت بتركيزات عالية لكل من الاوراق والجذر. كانت المعاملة (Fe+Mn) ذات تاثير سلبى على امتصاص المنجنيز خلال اعضاء النبات المختلفة (اوراق– ساق – جذر). كما ادت التركيزات العالية للمعاملات الثنائية والثلاثية لحدوث تراكم للمنجنيز فى الساق والنبات الكلى .

ادت المعاملات المختلفة بالحديد والمنجنيز والكوبلت سواء بصورة منفردة او متحدة الى زيادة الكربوهيدرات (الكلية – الذائبة وغير الذائبة)فى اعضاء النبات المختلفة (ساق – اوراق – جذر) وذلك بالمقارنة بالكنترول.

وبصفة عامة ادى التركيز العالى للحديد الى تقليل المحتوى من الكربوهيدرات فى كل من الاوراق والساق.أيضا ادى التركيز العالى من المنجنيز الى تقليل انتشار الكربوهيدرات الكلية والكربوهيدرات الغير ذائبة فى اجزاء النبات المختلفة. وقد لوحظ زيادة تراكم الكربوهيدرات فى الاوراق والساق عند اضافة التركيزات المختلفة من الكوبلت بصورة منفردة.

اظهرت الدراسة ان المعاملا ت المختلفة بمخاليط من العناصر الثقيلة Fe,Mn,Co كانت ذات تاثير ضار على المكونات المختلفة للكربوهيدرات وانتشارها خلال اعضاء النبات المختلفة