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EFFECT OF POTASSIUM AND MAGNESIUM FERTILIZATION ON THE GROWTH, SOME NUTRIENT STATUS AND K-Mg UPTAKE EFFICIENCY PARAMETERS OF CORN (*Zea mays L.*) GROWN ON SILTATION SOIL[1]

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ABSTRACT

A pot experiment with corn (Zea mays L., cv.TTM-813) was carried out on a completely randomized design with two factors. Potassium and magnesium were applied at the rates of 0, 10, 20, 30, 40 mg $K_2O.kg^{-1}$ as K_2SO_4 and 0, 10, 20, 30, 40 mg Mg kg^{-1} as MgO to the pots containing 5 kg of soil which are brought into cultivation after siltation made by Kelkit river. Phosphorus and N were applied at the rates of 40 mg $P_2O_5.kg^{-1}$ as triple superphosphate and 75 mg $N.kg^{-1}$ as urea respectively as basal fertilization. The plants were harvested 8 weeks after sowing. Potassium has significantly increased the growth of corns, regardless of applied levels, compared with control treatment. Increasing rates of magnesium has also significantly affected the growth of corn plant. 20 mg $K_2O.kg^{-1}$ and 20 $mg.kg^{-1}$ Mg were sufficient to increase the dry matter yield of plants. K-use efficiency, K-uptake efficiency and K-utilization efficiency were strongly related to the K application, on the other hand, Mg-use efficiency, Mg-uptake efficiency and Mg-utilization efficiency were strongly related to the Mg application. K and Mg-utilization efficiencies suggested that K:Mg ratio was an important factor for optimal growth and that proper nutrient uptake of the plants. It was concluded that application of Mg fertilizer must accompany K fertilizer application, especially in the siltation soils poor in available magnesium. Fe, Zn, Cu and Mn uptakes of plant gave different values depending on the dry matter yield and nutrient content of corn.

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SİLTASYON TOPRAĞINDA YETİŞTİRİLEN MISIR BİTKİSİNİN GELİŞİMİ VE BESLENME DÜZENİ İLE K-Mg ALIM ETKİNLİĞİNE POTASYUM VE MAGNEZYUM GÜBRELEMESİNİN ETKİSİ

ÖZET

Deneme, tesadüf parselleri deneme desenine göre iki faktörlü olarak yürütülmüş, bitki olarak TTM-813 mısır çeşidi kullanılmıştır. Potasyumlu gübre 0, 10, 20, 30 ve 40 mg $K_2O.kg^{-1}$ dozlarında ve K_2SO_4 formunda, magnezyumlu gübre ise 0, 10, 20, 30 ve 40 mg $Mg.kg^{-1}$ dozlarında ve MgO formunda 5 kg toprak içeren saksılara uygulanmıştır. Araştırmada kullanılan toprak, Kelkit çayından siltasyonla tarıma yeni kazandırılan sahadan elde edilmiştir. Normal bitki gelişimi için ayrıca 40 mg $P_2O_5.kg^{-1}$ dozunda fosfor, triple superfosfat ve 75 mg $N.kg^{-1}$ dozunda azot, üre formunda uygulanmıştır. Bitkiler çimlenmeyi takiben 8 haftalık bir süre sonunda hasat edilmiştir. Potasyumlu gübre uygulaması mısır bitkisi gelişimini kontrole göre önemli ölçüde etkilemiş, ancak 10, 20, 30 ve 40 $mg.kg^{-1}$ K_2O dozları arasında önemli bir fark ortaya çıkmamıştır. Artan dozlarda magnezyum uygulaması da mısır gelişimini önemli düzeyde etkilemiştir. Bitki kuru madde verimi açısından 20 $mg.kg^{-1}$ K_2O ve 20 $mg.kg^{-1}$ Mg uygulamaları yeterli bulunmuştur. Magnezyum uygulaması K-kullanım etkinliği, K-alım etkinliği ve K'dan yararlanma oranına, diğer taraftan potasyum uygulaması Mg-kullanım etkinliği, Mg-alım etkinliği ve Mg'den yararlanma oranına önemli etkide bulunmuştur. K ve Mg kullanım etkinliği ile ilgili parametreler, optimal bitki gelişimi ve beslenme düzeni açısından K:Mg oranının önemli bir faktör olduğunu ortaya koymuştur. Bu durum, örneğin siltasyon alanlarında olduğu gibi özellikle Mg açısından yoksun olan topraklarda potasyumlu gübrelemenin magnezyumla orantılı olarak yapılması gerektiğini ortaya koymaktadır. Mısır bitkisince sömürülen Fe, Zn, Cu ve Mn miktarları da, gerek bitki kuru madde miktarı ve gerekse besin kapsamına bağlı olarak farklı değerler vermiştir.

INTRODUCTION

Maximization of agricultural production through the application of K fertilizer can be accomplished by satisfying the interactions between potassium and other nutrients. Potassium and Mg fertilizers have a positive effect on many plants (Aksoy, 1979; Hout, 1988; Mitra et al., 1990) and the K x Mg antagonistic interaction negatively affects growth and yields of many plants (Grimme et al., 1974; Koukoulakis et al., 1991). Application of Mg fertilizer must necessarily accompany K fertilizer application in soils low in available Mg which can not be abstained from adding K fertilizers (Koukoulakis et al., 1991). K:Mg is an important factor for optimal growth and proper nutrient status of plant, especially, grown on artificial siltation soils which are poor in fertility.

The siltation working was carried out as Tokat-Niksar-Yarbaşı project by the Directorate of Village Affairs of Ministry of Agriculture of Turkey. It comparises 700 hectares. The bunds are established at 250 meters distance and silty water of Kelkit was applied to these protected areas for silt deposit. Artificial siltation areas are generally poor in nutrients. Because siltation is done through the decantation method that is muddy water of the river is applied to Lands which are protected with soil bunds (Anonymous,1993). The purpose of this research work was to determine the effect of potassium and magnesium fertilization on the gowth, some nutrient status and K-Mg uptake efficiency parameters of corn (Zea mays L.) grown on siltation soil.

2. MATERIALS and METHODS

A pot experiment was carried out on a completely randomized design with two factors and three replications. Factorial combinations of 0, 10, 20, 30, 40 $mg.kg^{-1}$ K_2O as K_2SO_4 and 0, 10, 20, 30, 40 $mg.kg^{-1}$ Mg as MgO were applied to the pots containing 5 kg of soil which are brought into cultivation after siltation made by Kelkit river in Tokat-Turkey. Three TTM-813 corn seeds per pot were sown on 30th June, 1996. Phosphorus and N were applied at the rates of 40 mg $P_2O_5.kg^{-1}$ as triple superphosphate and 75 mg $N.kg^{-1}$ as urea respectively as basal fertilization. The plants were harvested on 3rd September, 1996 (after 8 weeks). The dry matter yields of corn were recorded. Potassium, Mg, Fe, Zn, Cu and Mn contents of plant (straw + leaf) were determined by atomic absorption spectrophotometer (Perkin, 1971).

The alluvial soil used in the pot experiment was silty-loam (13.46 %, 65.40 % and 21.14 % clay, silt and sand, respectively), 21.11 % field capacity and 20.18 % $CaCO_3$. The pH was 8.12, EC was 204 $\mu mhos.cm^{-1}$ and organic matter content (Walkley,1947) was 0.81 %. The cation exchange capacity (Chapman and Pratt, 1961) was 20.11 $me.100gr^{-1}$. The exchangable K (NH_4Ac-extract, Knudsen et al., 1982) and Mg (Thomas, 1982) contents were 5.55 and 3.11 me.100 gr^{-1}. The available P (Olsen et al.,1954) and Fe, Cu, Zn, Mn contents (with DTPA, Perkin, 1971) were 7.38, 5.21, 3.34, 0.39 and 5.48 $mg.kg^{-1}$ respectively.

Leaf+straw dry weight (dw), K and Mg uptake (Kt, Mgt), K and Mg fertilizer rate (K_f, Mg_f) were used to calculate the K and Mg uptake efficiency parameters. K-use efficiency (dw/K_f), K-uptake efficiency (Kt/K_f), K-utilization efficiency (dw/Kt), Mg-use efficiency (dw/Mg_f), Mg-uptake efficiency (Mgt/Mg_f) and Mg-utilization efficiency (dw/Mgt) were calculated for corn plant (modified from Moll et al., 1982). Uptake and utilization efficiency can be combined, $dw / f = (t / f) (dw / t)$, to obtain use efficiency;

RESULTS and DISCUSSION

Effect Of Potassium And Magnesium Fertilization On The Growth, Some Nutrient Status And K-Mg Uptake Efficiency Parameters Of Corn (*Zea Mays L.*) Grown On Siltation Soil

Effect of K and Mg fertilization on the dry matter yield of corn

Increasing rates of potassium sulphate significantly increased the dry matter yield of plants. There was no istatistical difference among the potassium rates. It was also seen that potassium and magnesium interaction had very significant effect on the dry matter yield.

The maximum dry matter yield of 20.72 $gr.pot^{-1}$ was obtained at 20 $mg.kg^{-1}$ K_2O and 20 $mg.kg^{-1}$ Mg treatments (Table 1). Magnesium had no significant effect on the dry matter yield of plants after 30 and 40 $mg.kg^{-1}$ Mg rates. This showed that Mg fertilizer must necessarily accompany K fertilizer application at the proper K:Mg ratio for optimal plant growth. Similar conclusions were made by other workers (Grimme et al., 1974; Koukoulakis et al., 1991).

Table 1. Effect of K and Mg fertilization on dry matter yield of corn (leaf + straw). $gr.pot^{-1}$

K_2O $Mg.kg^{-1}$	Mg, $mg.kg^{-1}$ 0	10	20	30	40
0	15.26 e	17.11 be	18.25 ad	16.93 ce	19.44 ac
10	17.94 ad	18.66 ac	19.09 ac	20.29 a	18.60 ad
20	18.75 ac	15.77 de	20.72 a	20.07 a	19.91 ab
30	18.68 ac	18.66 ac	19.66 ac	19.64 ac	18.44 ad
40	20.27 a	18.73 ac	18.31 ad	17.97 ad	18.13 ad

LSD (potassium x magnesium) = 2.433 **
***; Significant at 1 % level, statistically.*

These workers reported that the lack of response to K was attributed K-Mg antagonism. They suggested that it was necessary to combine K application with Mg fertilizer in order to overcome the adverse effect of the KxMg interaction on yields. It has also been reported that the addition of potassium and magnesium has become essential to get profitable yields of cereals (Burkart, 1975; Aksoy, 1979; Hout, 1988; Mitra et al., 1990).

Effect of K and Mg fertilization on the K and Mg contents of corn

It can be seen from the results that K content of corn plant (leaf+straw) was increased with increasing potassium rates regardless of applied Mg (Table 2). In the control treatment, an average K content of 2.70 % was determined, whereas, it was 3.01 % in the 40 $mg.kg^{-1}$ K_2O treatment. Similar results have also been observed by many other workers (Hout, 1988; Katsadonis et al.,1991).

Magnesium application had no significant effect on the K content of corn plant. A considerable decrease was observed in the Mg contents of corn as a result of different levels of potassium (Table 3). In the control treatment, an average Mg content of 0.38 % was determined, whereas it was regularly decresed with increasing rates of potassium application. Similar results have been observed by others (Grimme et al.,1974; Koukoulakis et al., 1991). These workers found that total K content inceased and total Mg content decreased with increasing rates of potassium application. It was also reported that the ratio K:Mg in crop leaf could be used as an index value for the interpretation of leaf analysis.

Table 2. Effect of K and Mg fertilization on the K content of corn, %.

K_2O Mg.kg^{-1}	Mg, mg.kg^{-1} 0	10	20	30	40	Av.
0	2.77	2.68	2.68	2.63	2.72	2.70 BC
10	2.59	2.75	2.67	2.48	2.52	2.60 C
20	2.52	2.79	2.82	2.72	2.96	2.76 ABC
30	2.61	3.16	2.95	3.19	2.70	2.92 AB
40	2.74	2.92	3.16	3.11	3.14	3.01 A

LSD (K_2O) = 0.066 **; LSD (Mg) = N.S.; LSD (potassium x magnesium) = N.S

Table 3. Effect of K and Mg fertilization on the Mg content of corn, %.

K_2O Mg.kg^{-1}	Mg, mg.kg^{-1} 0	10	20	30	40	Av.
0	0.27	0.33	0.38	0.42	0.48	0.38 A
10	0.25	0.32	0.37	0.41	0.47	0.37 A
20	0.23	0.29	0.30	0.34	0.39	0.31 B
30	0.18	0.24	0.23	0.27	0.35	0.25 C
40	0.17	0.20	0.24	0.25	0.30	0.23 C
Av.	0.22 D	0.28 C	0.30 C	0.34 B	0.40 A	

LSD (K_2O) = 0.031 ** ; LSD (Mg) = 0.031 ** ; LSD (potassium x magnesium) = N.S.

***; Significant at 1 % level, N.S.; Non-significant, statistically.*

Effect of K and Mg fertilization on the Fe, Zn, Cu and Mn contents of corn

It was seen that potassium and magnesium interaction had very significant effect on the Fe, Zn and Cu contents of corn plant (leaf+straw) (Table 4, 5 and 6). The maximum Fe content of 204.62 mg.kg^{-1} was obtained at 20 mg.kg^{-1} K_2O and control Mg treatments. The maximum Zn content of 36.30 mg.kg^{-1} was obtained at 40 mg.kg^{-1} K_2O and 20 mg.kg^{-1} Mg treatments, whereas the maximum Cu content of 26.09 mg.kg^{-1} was obtained at control K_2O and 20 mg.kg^{-1} Mg treatments.

from 176.48 mg.kg^{-1} (control) to 151.48 mg.kg^{-1} (40 mg.kg^{-1} K_2O). It increased the Zn-content from 24.11 mg.kg^{-1} (control) to 30.52 mg.kg^{-1} (40 mg.kg^{-1} K_2O). Potassium application has no effect on the Cu and Mn-contents of corn plant. Magnesium application generally decreased Fe-content from 192.34 mg.kg^{-1} (control) to 149.74 mg.kg^{-1} (40 mg.kg^{-1} K_2O), and decreased the Mn-content from 113.8 mg.kg^{-1} (control) to 108.8 mg.kg^{-1} (40 mg.kg^{-1} K_2O), whereas it had no significant effect on the Zn and Cu-contents of the plants.

Different rates of potassium applied to corn plant first increased the plant (leaf + straw) Fe-content (191.96 mg.kg^{-1}) at 20 mg.kg^{-1} K_2O, and then decreased the Fe-content

Table 4. Effect of K and Mg fertilization on the Fe content of corn, mg.kg^{-1}.

K_2O Mg.kg^{-1}	Mg, mg.kg^{-1} 0	10	20	30	40
0	189.09 ac	187.18 ac	173.74 bc	169.17 c	163.23 c
10	199.35 ab	200.00 ab	163.03 c	162.88 c	162.65 c
20	204.62 a	190.68 ac	189.85 ac	190.31 ac	184.33 ac
30	203.48 a	186.74 ac	170.45 c	132.88 d	124.85 d
40	165.15 c	182.57 ac	175.76 bc	120.30 d	113.63 d

LSD (potassium x magnesium) = 23.731 **

Table 5. Effect of K and Mg fertilization on the Zn content of corn, mg.kg^{-1}.

K_2O Mg.kg^{-1}	Mg, mg.kg^{-1} 0	10	20	30	40
0	25.12 ad	26.02 ad	23.32 bd	23.05 cd	23.01 cd
10	33.91 ac	18.03 d	22.22 d	21.08 d	22.84 cd
20	26.11 ad	21.07 d	23.66 bd	26.04 ad	22.04 d
30	24.99 ad	27.85 ad	26.39 ad	26.02 ad	28.09 ad
40	24.47bd	29.46 ad	36.30 a	34.83 ab	27.55 ad

LSD (potassium x magnesium) = 9.702 **

Table 6. Effect of K and Mg fertilization on the Cu content of corn, mg.kg^{-1}.

K_2O Mg.kg^{-1}	Mg, mg.kg^{-1} 0	10	20	30	40
0	24.22 ab	26.09 a	20.61 ac	13.39 cg	14.61 cg
10	11.17 eg	9.61 g	11.28 dg	14.28 cg	14.06 cg
20	10.73 fg	13.67 cg	18.50 af	14.56 cg	17.83 bg
30	19.56 ae	19.72 ad	16.33 bg	17.39 bg	14.44 cg
40	14.17 cg	15.22 cg	13.50 cg	13.50 cg	14.22 cg

LSD (potassium x magnesium) = 6.978 *

Table 7. Effect of K and Mg fertilization on the Mn content of corn, $mg.kg^{-1}$.

K_2O	$Mg, mg.kg^{-1}$				
$Mg.kg^{-1}$	0	10	20	30	40
0	116.4	133.6	109.0	108.8	107.4
10	122.6	113.9	133.5	111.1	110.4
20	113.7	126.6	107.0	108.6	108.5
30	109.7	112.2	110.1	109.8	109.6
40	106.7	111.5	111.3	109.2	107.9
Av.	113.8 AB	119.6 A	110.2 B	109.5 B	108.8 B

LSD (Mg) = 8.706 **

***; Significant at 1 % level; *; Significant at 5 % level, statistically.*

K-Mg-Uptake Efficiency Parameters in Corn

K-uptake of corn (leaf+straw) increased with increasing potassium rates, whereas the Mg-uptake of corn plant regularly decreased with increasing rates of potassium application (Figure 1 and 2). Potassium and magnesium uptake efficiency parameters depending on different K and Mg rates were also determined (Table 8 and 9).

Figure 1. Plant K-uptake, $mg.pot^{-1}$.

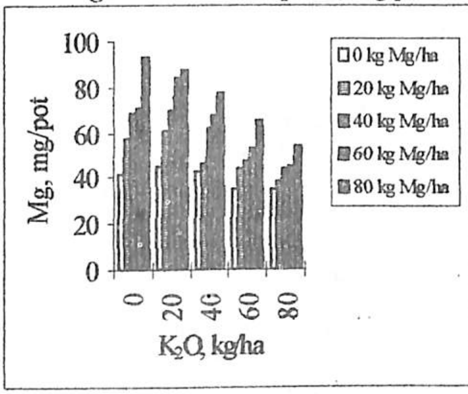
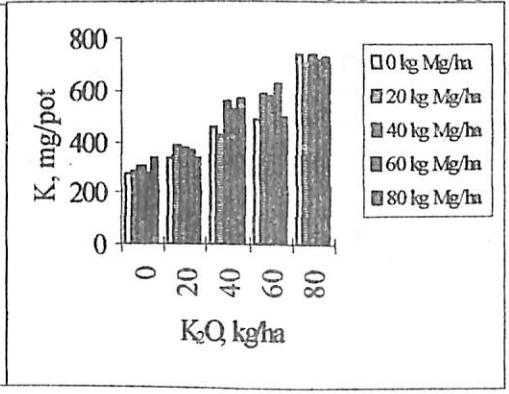


Figure 2. Plant Mg-uptake, $mg.pot^{-1}$.



K-use efficiency (dw/K_f), K-uptake efficiency (Kt/K_f) and Mg-utilization efficiency (dw/Kt) were strongly related to the K application, on the other hand, the Mg-use efficiency (dw/Mg_f), Mg-uptake efficiency (Mgt/Mg_f) and Mg-utilization efficiency (dw/Mgt) were strongly related to the Mg application.

It was apparent that increasing K fertilizer rates decreased the K-use, K-uptake and K-utilization efficiencies, and Mg fertilizer rates decreased the Mg-use, Mg-uptake and Mg-utilization efficiencies. However, K fertilizer rates strongly increased the Mg-utilization efficiency compared with the control treatment and Mg fertilizer rates slightly increased the K-utilization efficiency compared with the 50 $mg.pot^{-1}$ Mg rate. The results indicated that corn plant preferred to absorb K compared with Mg with increasing rates of potassium application, and that Mg-utilization was maintained with Mg application at high

K rates. Comparatively, less absorption of magnesium in the presence of potassium has also been observed by other workers (Grimme et al., 1974; Koukoulakis et al., 1991).

Table 8. K-Mg uptake efficiency parameters in corn at different K rates.

K mg.pot^{-1}	dw_{plant}	K-efficiency parameters			Mg-efficiency parameters*		
		dw/K_f	Kt/K_f	dw/Kt	dw/Mg_f	Mgt/Mg_f	dw/Mgt
0	17.40	-	-	37.02	-	-	263
41.49	18.92	456	11.86	38.46	151	0.56	272
82.98	19.04	229	6.33	36.27	152	0.47	323
124.47	19.02	153	4.47	34.15	152	0.39	389
165.96	18.68	113	3.40	33.24	149	0.34	434

* Mg-efficiency parameters were calculateted on a means of Mg rates (125 mg.pot^{-1})

Table 9. K-Mg uptake efficiency parameters in corn at different Mg rates.

Mg mg.pot^{-1}	dw_{plant}	Mg-efficiency parameters			K-efficiency parameters*		
		dw/Mg_f	Mgt/Mg_f	dw/Mgt	dw/K_f	Kt/K_f	dw/Kt
0	18.18	-	-	459	-	-	37.80
50	17.79	356	0.98	362	172	4.92	34.89
100	19.21	192	0.58	330	185	5.28	35.08
150	18.98	127	0.43	297	183	5.16	35.44
200	18.90	95	0.38	250	182	5.11	35.65

*K-efficiency parameters were calculateted on a means of K rates (103.7 mg.pot^{-1})

Effect of K and Mg fertilization on the Fe, Zn, Cu, Mn uptakes of corn

Increasing rates of potassium sulphate fertilizer first increased and then decreased the Fe and Mn uptakes of corn (Figure 3 and 6). Zinc uptake was increased, whereas Cu uptake was fluctuated with increasing potassium rates (Figure 4 and 5). Magnesium applied at different rates also increased the Mg uptake, whereas it decreased the Fe uptake of corn plant. Magnesium application statistically no important effect on the K, Zn, Cu and Mn uptakes of corn plant. This probably was dependent on the dry matter yield and nutrient content of plant. These results are parallel to the other studies carried out with different plants (Aksoy,1979; Sanchez,1984; Chakravorti,1989; Katsadonis et al.,1991; İnal et al.,1995).

As a result; it was concluded that 20 mg.kg^{-1} K_2O and 20 mg.kg^{-1} Mg were sufficient for increasing the dry matter yield of corn plant under the experimental conditions. Potassium and Mg-utilization efficiencies suggested that K:Mg ratio was an important factor for optimal growth and proper nutrient uptake of the plant, and that Mg fertilizer must necessarily accompany K fertilizer application at the proper K:Mg ratio, especially, in the siltation soils poor in available Mg. It was also concluded that the Fe, Zn, Cu and Mn uptakes of plant gave different values depending on the dry matter yield and nutrient content of corn.

Figure 3. Plant Fe-uptake, µg.pot^{-1}.

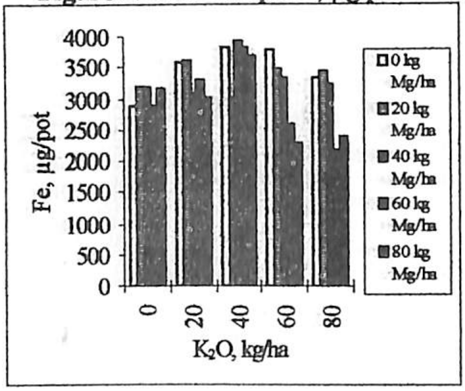


Figure 4. Plant Zn-uptake, µg.pot^{-1}.

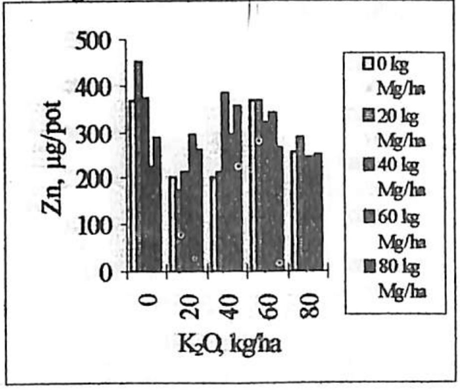


Figure 5. Plant Cu uptake, µg.pot^{-1}.

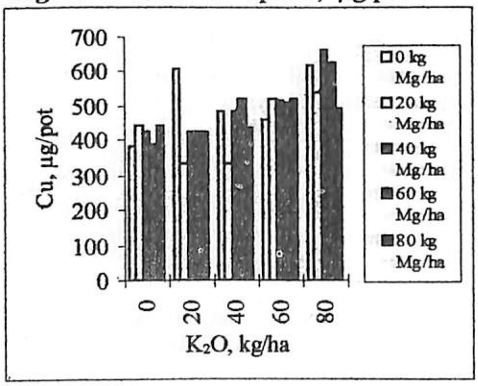
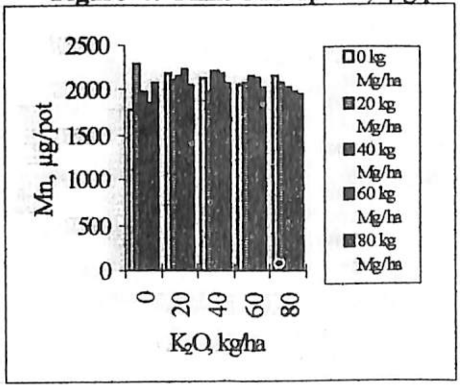


Figure 6. Plant Mn uptake, µg.pot^{-1}.



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