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Effects of humus on growth and nutrient uptake of maize under saline and calcareous soil conditions

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Abstract

Greenhouse research was conducted to determine the effects of soil application of humus, on dry matter and N, P, K, Ca, Mg, Fe, Cu, Zn, Mn and Na uptake of maize grown under calcareous and saline soil conditions. Stress conditions were obtained by adding 40% $CaCO_3$ and 60 mM NaCl to the soil. Humus was applied to the soils at 0, 1 and 2 g kg^{-1} doses at the beginning of the treatment. Solid humus and $CaCO_3$ were mixed according to the application doses, and the total weight of the soil was adjusted to 5 kg. The mixture was homogenised and put into polyethylene-covered plastic pots (20 x 18 cm). A 60 mM NaCl solution was added to the salt-treated pots.

$CaCO_3$ and NaCl both negatively affected the plants' growth, lowering the dry weights of the plants due to the stress, and decreasing the mineral nutrient amounts, except for sodium. Although the application of humus had no apparent affects on the control pots, which received no lime or salt applications, the humus applications had significant effects under the calcareous and saline conditions. The lower application dose of humus elevated the dry matter yield and some nutrient element uptakes under the stress conditions. The increases at the higher dose were found to be smaller than those at the lower dose of humus except for potassium and calcium uptake.

Soil application of humus could minimise the negative effects of saline and calcareous soil conditions on nutrient uptake and plant development but further studies are required to determine economical application levels.

Key words: humus, interaction, lime, salt, maize.

Introduction

With the continued and rapid increase in the world population, it has become of vital importance to obtain higher yields per unit area of agricultural production. For this reason, the plants' water and nutrient needs must be met. Calcareous soil conditions are an important factor for nutrient availability and agricultural production. Calcareous soils, which are defined as having significant quantities of free excess lime ($CaCO_3$ or $MgCO_3$), are very common in Mediterranean areas and represent the dominant soil type in many arid and semiarid climates, comprising over 600 million ha of soils worldwide (Leytem, Mikkelsen, 2005). Salinity is another common problem in these climates (Li et al., 2005). Calcareous soils particularly affect the soil properties related to plant growth, whether they are physical, such as the soil-water relations, or chemical, such as its fertility and the availability of plant nutrients (FAO, 1973). Excess calcium carbonate poses serious problems to plant nutrition; it raises the pH of soil to high levels (8.0 to 8.4) at which plant nutrients are relatively unavailable. Increased losses of nitrogen ammonia and reduced solubility of phosphorus occur in these types of soil. The micronutrients zinc, iron, manganese and copper tend to be less available at higher pH levels. Thus, this negatively affects soil fertility (Mortvedt, 2000; Çelik et al., 2008).

Plant growth and yield are reduced in salt-affected soil because of the excess uptake of potentially toxic ions (Grattan, Grieve, 1999). Soil salinity is characterised by high amounts of Na^+, Mg^{2+}, Ca^{2+}, Cl^-, HCO_3^-, SO_4^{2-} ions and boron (B), which have negative effects on plant growth. The general effect of soil salinity on plants is called a physiological drought effect. The high salt content decreases the osmotic potential of soil water, and consequently, this reduces the availability of soil water for plants. Briefly, the uptake of water by plant roots is limited by increased amounts of Na and Cl. Eventually; high salt concentrations in the soil reduce the plants' absorption of nutrients. Thus, salinity negatively affects the fertility of the soil (Pessarakli, Tucker, 1988; Grattan, Grieve, 1999; Aşık et al., 2009).

The fertility of soils is also related to their organic matter (OM) contents. Humic substances (humic and fulvic acids) are the major components of soil organic matter, and the term "humus" is widely accepted as a synonym for soil organic matter (Chen, Aviad, 1990). Humic substances improve soil fertility by modifying the physical, chemical and biological conditions in the soil. In many studies, humic substances have shown positive effects on plant biomass (Chen, Aviad, 1990; Lobartini et al., 1997; Nardi et al., 2002). These substances affect the solubility of many nutrient elements by building complex forms or chelating agents of humic matter with metallic cations (Lobartini et al., 1997).

Recent studies (Chen, Aviad, 1990; Nardi et al., 2002; Çelik et al., 2008; Aşık et al., 2009) have summarised the effects of humic substances on plant growth and mineral nutrition and their positive effects on seed germination, seedling growth, root initiation, root growth, shoot development and the uptake of macro- and microelements. Masciandaro et al. (2002) also pointed out that humic substances might counteract abiotic stress conditions (e.g., unfavourable temperature, pH, and salinity) enhancing the uptake of nutrients and reducing the uptake of some toxic elements. However, the growth response of plants has not been adequately studied under abiotic stress conditions.

The purpose of this work was to determine the effects of soil application of humus on the growth and nutrient uptake of maize grown under saline and calcareous soil conditions.

Materials and methods

The soil used in this study was collected from a 0–20 cm depth in a field located at the Agricultural Research and Application Center of Uludag University. The soil was classified as Vertisol (*Typic Haploxerert*) according to Soil Taxonomy and as *Eutric Vertisol* according to the FAO/Unesco soil classification system (Özsoy, Aksoy, 2004).

Some physical and chemical properties of the soil were analysed. Its texture was determined by the hydrometer method (Tan, 2005). Its pH and electrical conductivity (EC) were measured in a 1:2.5 water extract and lime was determined according to the method of Tan (2005). Organic matter content was analysed according to the modified Walkley-Black method (Nelson, Sommers, 1982). Total nitrogen was determined according to the Kjeldahl method using a Buchi K-437/K-350 digestion/distillation unit (Tan, 2005). Available P was determined using a "Shimadzu UV 1208" model spectrophotometer according to the Olsen method (Tan, 2005). Exchangeable cations (Na, K, Ca and Mg) were extracted with ammonium acetate at pH 7.0 (Pratt, 1965) and were determined using an "Eppendorf Elex 6361" model flame photometer. Available Fe, Cu, Zn, and Mn were extracted with DTPA (diethylenetriaminepentaacetic acid) (0.005 M DTPA + 0.01 M $CaCl_2$ + 0.1 M TEA pH 7.3) (Lindsay, Norvell, 1978) and were determined using a "Philips PU9200x" model atomic absorption spectrophotometer. These chemical and physical properties of the soil used in the research are given in Table 1.

The experiment was conducted in a greenhouse using a completely randomised factorial design with three replications. Stress conditions were obtained by adding 40% $CaCO_3$ and 60 mM NaCl. Humus was applied to the soils at 0, 1 and 2 g kg^{-1} doses at the beginning of the treatment. Humus was obtained from solid Deltahumus (65% w/w, pH: 4.87, EC: 5.80 mS cm^{-1}) derived from leonardite, which is a commercial product of "Delta Chemicals Co".

Air-dried soil sample was passed through a 4-mm sieve. Solid humus and $CaCO_3$ were put into a large bowl according to the doses to be applied, and the total weight of the soil was adjusted to 5 kg. The mixture was homogenised and put into polyethylene-covered plastic pots (20-cm diameter x 18-cm depth). A 60 mM NaCl solution was added to the salt-treated pots. The pots were incubated for 30 days. A basal fertiliser consisting of nitrogen (100 mg kg^{-1} as NH_4NO_3), phosphorus (80 mg kg^{-1}), potassium (100 mg kg^{-1} as KH_2PO_4), and zinc (0.5 mg kg^{-1} as $ZnSO_4$) was applied to the pots before planting. Four hybrid maize plants (*Zea mays* L. cultivar 'Fleuri AG 92149') were grown in each pot.

After a two-month growing period, the plant materials were harvested and rinsed, first with tap water and twice with deionised water. They were dried in a forced-air oven at 70°C for 72 h and their dry weights were determined. The plant samples were ground and wet digested using a HNO_3 + $HClO_4$ mixture. Their total nitrogen content was determined by the Kjeldahl method (Tan, 2005) using a Buchi K-437, K-350 digestion/distillation unit. P was determined by the vanadomolybdophosphoric method (Lott et al., 1956) using a "Shimadzu UV-1208" spectrophotometer. Na, K and Ca were determined by the flame emission method (Horneck, Hanson, 1998) using an "Eppendorf Elex 6361" flame photometer. Fe, Mn, Zn and Cu were determined by atomic absorption spectrometry (Hanlon, 1998) using a "Philips PU 9200x" atomic absorption spectrophotometer ("Pye Unicam" Ltd., GB).

Statistical analysis of all of the data were performed using the *Tarist* statistical software, and the mean values were compared using the LSD (least significant differences) multiple range tests ($p < 0.01$ and $p < 0.05$).

Results and discussion

The soil used in the experiment had a sandy clay texture and neutral pH. It had low lime, salt and organic matter contents. The nitrogen, phosphorus and zinc contents of the soil were not adequate (Table 1).

Table 1. Some chemical and physical properties of the soil used in the experiment

Texture class			pH	EC mS cm^{-1}	$CaCO_3$ %	OM %	N %	P mg kg^{-1}	Exchangeable cations mg kg^{-1}				Available micronutrients mg kg^{-1}			
Sandy clay																
Sand %	Loam %	Clay %							Na	K	Ca	Mg	Fe	Cu	Zn	Mn
45.15	15.22	39.63	7.24	0.83	0.22	1.30	0.08	7.96	39.1	175.5	3852	282	5.56	1.30	0.20	10.44

The effects of the soil application of humus on growth, the uptake of mineral nutrients and their interactions between lime levels are given in Tables 2–4. Lime and salt negatively affected seed germination and decreased the dry weight yield of the maize plants (Table 2). While the dry weight of the maize plants averaged 21.94 g pot^{-1} in the control pots, they averaged only 0.92 g pot^{-1} in the pots to which salt and lime had been applied. The high salt content decreased the osmotic potential of soil water and, consequently, reduced the availability of soil water for plants. Briefly, germination and the uptake of water by plant roots were limited by increased amounts of Na and Cl.

Table 2. Effects of soil applied humus on dry matter yield of maize (g pot^{-1})

Salt (SA) mM	Lime (LI) %	Humus (HU) g kg^{-1} 0		1		2		Mean
0	0	21.94 a	B	24.22 a	A	21.53 a	B	22.56 a
	40	3.94 b	B	9.68 b	A	9.57 b	A	7.73 b
	Mean	12.94 **a**	B	16.95 **a**	A	15.55 **a**	A	15.15 **a**
60	0	10.77 a	B	12.79 a	A	11.06 a	AB	11.54 a
	40	0.92 b	B	1.39 b	B	3.82 b	A	2.04 b
	Mean	5.85 **b**	B	7.09 **b**	AB	7.44 **b**	A	6.79 **b**
Total mean		9.39	B	12.02	A	11.50	A	

$HU_{LSD<0.01}$: 1.345 $SA \times LI_{LSD<0.01}$: 1.554 $HU \times SA \times LI_{LSD<0.05}$: 1.987

$SA_{LSD<0.01}$: 1.099 $HU \times SA_{LSD<0.05}$: 1.405

Notes. The differences between values by different letters are significant. Capital letters for each row and small letters for each column.

The lime and salt levels also had negative effects on the uptake of some macro- and micronutrient elements (Tables 3 and 4). In control pots, the maize plants took up 408.64 g N pot^{-1}, 66.55 g P pot^{-1}, 478.80 g K pot^{-1}, 89.72 g Ca pot^{-1}, 67.79 g Mg pot^{-1}, 1.70 g Fe pot^{-1}, 0.18 g Zn pot^{-1}, 0.09 g Cu pot^{-1} and 1.53 g Mn pot^{-1}, while in pots that received salt and lime applications, the plants took up only 30.97 g N pot^{-1}, 1.37 g P pot^{-1}, 23.01 g K pot^{-1}, 10.36 g Ca pot^{-1}, 3.24 g Mg pot^{-1}, 0.08 g Fe pot^{-1}, 0.01 g Zn pot^{-1}, 0.01 g Cu pot^{-1} and 0.09 g Mn pot^{-1}.

Calcareous soils are characterised by high carbonate contents, high Ca^{2+} concentrations in the soil solution and high pH levels (Mengel, Kirkby, 1982). Micronutrient deficiencies often occur in plants grown in calcareous soils because of high pH (Kacar, Katkat, 2009). Similarly, in saline soil, the solubility of micronutrients is particularly low, and plants grown in saline soils often show micronutrient deficiencies (Page et al., 1990). Many laboratory and greenhouse studies have also shown that salinity can reduce N accumulation (Alam, 1994), P concentration (Navarro et al., 2001) and K uptake in plants due to competition by Na (Lopez, Satti, 1996). High Na in the soil solution also has an antagonistic effect on the uptake of Ca and Mg (Bernstein, 1975). This antagonism is most likely caused by the displacement of Ca in membranes of root cells (Yermiyahu et al., 1997). The solubility of the plant nutrients was negatively affected, and all of these factors caused poor development of the plants.

Although the effects of increasing amounts of humus applications on the dry weight yield of maize were not found to be statistically significant in control plots, they were statistically significant under stress conditions. The dry weight was 1.39 g pot^{-1} at the first dose of humus and it increased to 3.82 g pot^{-1} with the second dose of humus. Under calcareous soil conditions, the first and second applications of humus increased the dry-weight yield from 3.94 g pot^{-1} to 9.68 g pot^{-1} and 9.57 g pot^{-1}, respectively. Under saline soil conditions, the first and second applications of humus increased the dry-weight yield from 10.77 g pot^{-1} to 12.79 g pot^{-1} and 11.06 g pot^{-1}, respectively. Türkmen et al. (2004) and Gülser et al. (2010) similarly reported that 1000 mg kg^{-1} of humic acid application positively affected the growth of tomato and pepper plants grown under saline soil conditions, but high doses of humic acid inhibited plant growth.

The soil application of humus had a statistically significant effect on the uptake of nutrient elements ($p < 0.01$) except for Fe and Na (Table 3 and 4). Under saline and calcareous soil conditions, increasing amounts of humus elevated the nutrient uptake compared to the control. The highest values, except for Na, were found with the second dose of humus. Under stress conditions, the highest nutrient uptakes from the second dose of humus were 75.71 g N pot^{-1}, 4.75 g P pot^{-1}, 102.33 g K pot^{-1}, 19.75 g Ca pot^{-1}, 14.39 g Mg pot^{-1}, 0.20 g Fe pot^{-1}, 0.05 g Zn pot^{-1}, 0.03 g Cu pot^{-1} , and 0.40 g Mn pot^{-1}.

According to the general mean values, the highest uptakes of N (227.06 g pot^{-1}), P (29.61 g pot^{-1}), Mg (46.19 g pot^{-1}), Fe (0.77 g pot^{-1}), Mn (1.09 g pot^{-1}) and Na (5.14 g pot^{-1}) were found after the lower dose of humus (1 g kg^{-1}). The highest uptakes of K (304.43 g pot^{-1}) and Ca (59.38 g pot^{-1}) were measured at the higher dose of humus (2 g kg^{-1}). Zinc (0.11 g pot^{-1}) and Cu (0.10 g pot^{-1}) uptakes were not affected by the higher dose of humus. Various researchers (Chen, Aviad, 1990; Erdal et al., 2000; Ahmed et al., 2010) have reported increases in plant growth and nutrient uptake with the application of humic acid. Tan (2003) determined a significant increase in N content and stimulated dry matter production from corn seedling shoots. Humic matter can affect the solubility of insoluble phosphorus compounds in soil by its chelation capacity, and chelated metals are also available to plants by exchange (Tan, 2003). When humus-treated soils are fertilised, exchange and chelation sites become saturated with macro- and micronutrients, and plant roots can thus obtain the adsorbed cations by cation exchange. This exchange between humic matter and plant roots is also important for the salt balance of the soil. High salt concentrations, which are usually toxic to plants, can be alleviated by the adsorption of humic acid. This exchange, facilitated by humic acid, allows plants to grow within a wide pH range (Tan, 2003). Our results confirm earlier findings that humic acid can increase the uptake of nutrient elements and stimulate the dry matter production of shoots under saline and calcareous soil conditions.

Table 3. Effects of humus on some macronutrients uptake of maize (mg tdw^{-1})

Salt (SA) mM	Lime (LI) %	Humus (HU) g kg^{-1}						
		0		1		2		Mean
		Nitrogen (N)						
0	0	408.68		433.67		422.09		421.48 a
	40	127.18		217.43		185.85		176.82 b
	Mean	267.93 **a**	B	325.55 **a**	A	303.97 **a**	A	299.15 **a**
60	0	230.90		205.28		202.79		212.99 a
	40	30.97		51.86		75.71		52.85 B
	Mean	130.94 **b**	A	128.57 **b**	A	139.25 **b**	A	132.92 **b**
Total mean		199.44	B	227.06	A	221.61	A	
$HU_{LSD<0.01}$: 19.754		$SA_{LSD<0.01}$: 16.129	SA x $LI_{LSD<0.01}$: 22.810		HU x $SA_{LSD<0.01}$: 27.937		HU x SA x LI_{LSD}: ns	
		Phosphorus (P)						
0	0	66.55		72.69		61.26		66.83 a
	40	4.11		12.66		12.90		9.89 b
	Mean	35.33 **a**	B	42.67 **a**	A	37.08 **a**	B	38.36 **a**
60	0	29.74		31.32		25.99		29.01 a
	40	1.37		1.78		4.75		2.63 b
	Mean	15.55 **b**	A	16.55 **b**	A	15.37 **b**	A	15.82 **b**
Total mean		25.44	B	29.61	A	26.23	B	
$HU_{LSD<0.01}$: 3.352		$SA_{LSD<0.01}$: 2.737	SA x $LI_{LSD<0.01}$: 3.871		HU x $SA_{LSD<0.05}$: 3.501		HU x SA x LI_{LSD}: ns	
		Potassium (K)						
0	0	478.80 a	A	491.87 a	A	468.66 a	A	479.78
	40	95.92 b	B	214.62 b	A	288.90 b	A	199.81
	Mean	287.36		353.25		378.78		339.80 **a**
60	0	256.03 a	B	331.07 a	AB	357.82 a	A	314.97
	40	23.01 b	A	34.17 b	A	102.33 b	A	53.17
	Mean	139.52		182.62		230.07		184.07 **b**
Total mean		213.44	B	267.93	A	304.43	A	
$HU_{LSD<0.01}$: 54.415		$SA_{LSD<0.01}$: 44.430	SA x LI_{LSD}: ns		HU x SA_{LSD}: ns		HU x SA x $LI_{LSD<0.05}$: 80.359	
		Calcium (Ca)						
0	0	89.72 a	A	88.63 a	A	89.11 a	A	89.15 a
	40	33.54 b	B	59.84 b	A	54.99 b	A	70.97 b
	Mean	61.63		74.24		72.05		69.31 **a**
60	0	65.69 a	A	73.56 a	A	73.68 a	A	49.46 a
	40	10.36 b	A	12.72 b	A	19.75 b	A	14.28 b
	Mean	38.03	B	43.14		46.71		42.63 **b**
Total mean		49.83		58.69	A	59.38	A	
$HU_{LSD<0.01}$: 7.151		$SA_{LSD<0.01}$: 5.839	SA x $LI_{LSD<0.01}$: 8.258		HU x SA_{LSD}: ns		HU x SA x $LI_{LSD<0.05}$: 10.561	
		Magnesium (Mg)						
0	0	67.79		88.82		70.20		75.61
	40	15.50		31.38		32.41		26.43
	Mean	41.64		60.10		51.30		51.02 **a**
60	0	43.01		60.12		51.75		51.63
	40	3.24		6.61		14.39		8.08
	Mean	23.13		33.37		33.07		29.85 **b**
Total mean		32.39	B	46.19	A	42.19	A	
$HU_{LSD<0.01}$: 7.950		$SA_{LSD<0.01}$: 6.491	SA x LI_{LSD}: ns		HU x SA_{LSD}: ns		HU x SA x LI_{LSD}: ns	

Notes. The differences between values by different letters are significant. Capital letters for each row and small letters for each column; tdw – total dry weight, ns – not significant.

Table 4. Effects of humus on some micronutrients uptake of maize (mg tdw^{-1})

Salt (SA) mM	Lime (LI) %	Humus (HU) g kg^{-1} 0		1		2		Mean
				Iron (Fe)				
0	0	1.70		1.55		1.42		1.56 a
	40	0.25		0.67		0.48		0.47 b
	Mean	0.98 **a**	B	1.11 **a**	A	0.95 **a**	B	1.01 **a**
60	0	0.81		0.71		0.80		0.78 a
	40	0.08		0.13		0.20		0.14 b
	Mean	0.45 **b**	A	0.42 **b**	A	0.50 **b**	A	0.46 **b**
Total mean		0.71		0.77		0.73		
HU_{LSD}: ns	$SA_{LSD<0.01}$: 0.104	$SA \times LI_{LSD<0.01}$: 0.147		$HU \times SA_{LSD<0.05}$: 0.133		$HU \times SA \times LI_{LSD}$: ns		
				Copper (Cu)				
0	0	0.09 a	B	0.21 a	A	0.22 a	A	0.17 a
	40	0.03 b	B	0.08 b	A	0.08 b	A	0.06 b
	Mean	0.06 **a**	B	0.15 **a**	A	0.15 **a**	A	0.12 **a**
60	0	0.08 a	A	0.10 a	A	0.08 a	A	0.09 a
	40	0.01 b	A	0.01 b	A	0.03 b	A	0.02 b
	Mean	0.05 **a**	A	0.06 **b**	A	0.06 **b**	A	0.05 **b**
Total mean		0.05	B	0.10	A	0.10	A	
$HU_{LSD<0.01}$: 0.022	$SA_{LSD<0.01}$: 0.018	$SA \times LI_{LSD<0.01}$: 0.025		$HU \times SA_{LSD<0.01}$: 0.031		$HU \times SA \times LI_{LSD<0.05}$: 0.032		
				Zinc (Zn)				
0	0	0.18 a	A	0.20 a	A	0.20 a	A	0.19 a
	40	0.05 b	B	0.09 b	A	0.09 b	A	0.08 b
	Mean	0.11 **a**	B	0.15 **a**	A	0.15 **a**	A	0.14 **a**
60	0	0.12 a	A	0.14 a	A	0.09 a	B	0.11 a
	40	0.01 b	B	0.03 b	AB	0.05 b	A	0.03 b
	Mean	0.07 **b**	B	0.08 **b**	A	0.07 **b**	AB	0.07 **b**
Total mean		0.09	B	0.11	A	0.11	A	
$HU_{LSD<0.01}$: 0.014	$SA_{LSD<0.01}$: 0.012	$SA \times LI_{LSD<0.01}$: 0.017		$HU \times SA_{LSD<0.05}$: 0.015		$HU \times SA \times LI_{LSD<0.01}$: 0.029		
				Manganese (Mn)				
0	0	1.53		1.84		1.41		1.60
	40	0.41		1.08		0.59		0.70
	Mean	0.97 **a**	B	1.47 **a**	A	1.00 **a**	B	1.15 **a**
60	0	1.10		1.27		1.18		1.18
	40	0.09		0.16		0.40		0.22
	Mean	0.59 **b**	B	0.72 **b**	AB	0.79 **b**	A	0.70 **b**
Total mean		0.78	B	1.09	A	0.90	B	
$HU_{LSD<0.01}$: 0.140	$SA_{LSD<0.01}$: 0.114	$SA \times LI_{LSD}$: ns		$HU \times SA_{LSD<0.01}$: 0.198		$HU \times SA \times LI_{LSD}$: ns		
				Sodium (Na)				
0	0	3.57		3.31		3.05		3.31
	40	0.80		1.45		2.33		1.53
	Mean	2.19		2.38		2.69		2.42 **b**
60	0	9.34		9.37		7.77		8.83
	40	2.82		6.45		5.30		4.86
	Mean	6.08		7.91		6.54		6.84 **a**
Total mean		4.13		5.14		4.61		
HU_{LSD}: ns	$SA_{LSD<0.01}$: 1.526	$SA \times LI_{LSD}$: ns		$HU \times SA_{LSD}$: ns		$HU \times SA \times LI_{LSD}$: ns		

Notes. The differences between values by different letters are significant. Capital letters for each row and small letters for each column; tdw – total dry weight, ns – not significant.

Conclusions

1. Humus has beneficial effects on nutrient uptake, transport and availability to the plant and it enhances stress tolerance. The application of humus might ameliorate the harmful effects of saline and calcareous soil conditions which can inhibit plant growth and nutrient uptake.

2. The use of humus in combination with mineral fertilisers benefits agricultural yield and improves plant growth as well as the uptake of nutrients. Further studies are required to determine economically feasible application levels under field conditions.

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Humuso trąšų įtaka kukurūzų augimui ir maisto medžiagų įsisavinimui esant druskingam bei kalkingam dirvožemiui

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Santrauka

Tyrimai atlikti šiltnamyje, siekiant nustatyti humuso trąšų įtaką kukurūzų, auginamų pakalkintame bei padruskintame dirvožemyje, sausųjų medžiagų kiekiui ir N, P, K, Ca, Mg, Fe, Cu, Zn, Mn bei Na įsisavinimui. Augalų streso būklė buvo sukelta į dirvožemį įterpus 40 % $CaCO_3$ ir 60 mM NaCl. Tyrimų pradžioje į dirvožemį buvo įterpta 0, 1 ir 2 g kg^{-1} humuso. Humusas ir $CaCO_3$ buvo sumaišyti pagal įterpimo normas, o dirvožemio bendras svoris buvo padidintas iki 5 kg. Mišinys homogenizuotas ir įdėtas į polietilenu uždengtus vegetacinius indus (20 x 18 cm). 60 mM NaCl tirpalo įpilta į numatytus druska apdoroti indus.

$CaCO_3$ ir NaCl turėjo neigiamą įtaką augalų augimui, nes dėl streso sumažėjo augalų sausųjų medžiagų svoris ir mineralinių maisto medžiagų kiekis, išskyrus natrio kiekį. Humuso įterpimas neturėjo ryškesnės įtakos kontroliniuose induose, į kuriuos kalkių ir druskos nebuvo įterpta, tačiau, esant pakalkintam ir padruskintam dirvožemiui, humuso įterpimas turėjo ryškų poveikį. Mažesnė humuso norma didino sausųjų medžiagų derlių ir kai kurių maisto medžiagų įsisavinimą esant streso sąlygoms. Įterpus didesnę humuso normą nustatytas mažesnis padidėjimas, palyginti su mažesne humuso norma, išskyrus kalio ir kalcio įsisavinimą.

Humuso įterpimas galėtų sumažinti druskingo ir kalkingo dirvožemio neigiamą poveikį augalų augimui ir maisto medžiagų įsisavinimui, tačiau tyrimus reikia tęsti, siekiant nustatyti ekonomiškai naudingus lygius.

Reikšminiai žodžiai: humusas, sąveika, kalkės, druska, kukurūzai.