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Nutrient Concentration and Distribution in Maize as Affected by Different Tillage Systems in the Çanakkale Province, Turkey

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Abstract: Tillage techniques affect the root absorption of macronutrients and trace elements. Our objective was to study the effect of conventional and two reduced tillage systems on the concentration of macro and micronutrients and their distribution in maize plant in area located near the Dardanelles Shore. The study was performed in a field experiment initiated in 2005 in a soil was a Forest Series Typic Haploxererts. The crops was wheat-vetch/maize in continuous sequence, in plots subjected to conventional tillage (MT) and two reduced tillage which are rototiller or shallow tillage (ST) and chisel tillage (CT). The experiment was a split-plot design, with three replications of each tillage treatment. Fertilizers were applied in year when wheat grown, averaging 150 kg N ha^{-1} $year^{-1}$ and 50 kg P ha^{-1} $year^{-1}$. Maize was sampled at midseason in 2007 and separated into roots, aboveground material. The crop was analyzed for nitrogen (N), potassium (K), sulfur (S), magnesium (Mg), calcium (Ca), sodium (Na), boron (B), zinc (Zn), manganese (Mn), iron (Fe), copper (Cu), aluminium (Al), barium (Ba), cadmium (Cd), cobalt (Co), chromium (Cr), nickel (Ni), lead (Pb), selenium (Se). Macronutrient concentrations were higher in leaf and stem biomass than in roots (i.e. N in leaves 28.5, 26.8 and 23.6 g kg^{-1}; roots 11.7, 10.6 and 12.4 g kg^{-1} in ST, MT and CT, respectively, in last year of experiment). Micronutrients concentrations were higher, with the exceptions of B, in roots than leaves and stems (i.e. Zn in leaves, 40.09, 36.50 and 34.10 mg kg^{-1}; roots 75.00, 99.80 and 74.00 mg kg^{-1} or Cr in leaves 29.72, 3.44 and 9.74 mg kg^{-1}; roots 66.25, 87.20 and 76.91 mg kg^{-1} in ST, MT and CT, respectively). The effects of tillage were limited for nutrient concentrations.

Key words: Tillage systems, macro-micro nutrients; maize

INTRODUCTION

The distribution pattern of macronutrients, micronutrients in topsoil is usually modified by the tillage systems (Lavado et al, 2001). Moreover, tillage techniques affect some soil properties like concentration of organic matter, pH, compaction, aeration and water availability. This gives rise to changes in bioavailability of several elements (Blevins et al., 1983) in root biomass distribution. All this processes affect the root absorption of macronutrients (Hargrove, 1985) and microelements (Carter and Gupta, 1997). Soil compaction and water availability, for example, have been shown to affect the uptake of major nutrients (N, P, K, Ca, Mg and S) and micronutrients (Mn, Fe, Zn, and Cu) (Shierlaw and Alston, 1984; Lipiec and Sptepniewski, 1995; Arvidsson, 1999). Tillage does not affect element absorption in a single way. In addition, nutrient availability changes continuously due to application of macro and micro nutrients through fertilizers, irrigation water or through indirect sources (i.e. car exhausts, rainfall and atmospheric deposition from several sources, etc.). Phosphorus fertilizers, especially are essential to obtain high productivity, however, they contain heavy metals that can contaminate the soil and threat the health of animals and humans. These changes in soil also affect the influence of tillage systems on the absorption of nutrients and other elements.

The agricultural production on the poor fertile soils of the Dardanelles Shore area was carried out with conventional tillage and without fertilizer from its start, 50 or 65 years ago. From the last years, both the use of various reduced tillage systems, and fertilization are increasing dramatically. The widespread use of this technology along the time will affect the soil properties of the region.

The objective of the study was to evaluate the effect of three tillage systems, conventional tillage using mouldboard plough (traditional system), shallow tillage using rototiller and chisel tillage (increasingly using in the last years) on the concentration of macro and micro nutrients and their distribution in maize aboveground biomass (leaves and stems) and roots in a clay loam soil after vetch cover crop killing using as green manure at the spring during three growing seasons.

MATERIAL and METHOD

The study was performed in a field experiment at the Agricultural Experimental Area located in Dardanos (39^o 30'N; 26^o 80'E). The soil was Typic Haploxererts (US soil taxonomy) or Eutric Vertisols (FAO/UNESCO). The main characteristics of this soil (0-30 cm) three year ago before the start of the study are: 13.4 g kg^{-1} organic carbon; 0.22 g kg^{-1} total nitrogen, 46.68 mg kg^{-1} available phosphorus; 304 g kg^{-1} clay; 399 g kg^{-1} sand; 298 g kg^{-1} silt; 7.69 pH; and 1.3 g cm^{-3} of bulk density. Annual rainfall and temperature averaged 600 mm and around 15 °C. Soil water content was adequate for planting in all experimental years. The Experiment started in 2003 and from that year wheat-vetch/maize was cropped in continuous sequence, with plots subjected to shallow tillage (ST), chisel tillage (CT) and conventional tillage (CT) using as traditional tillage system in this area in all cropping system. The CT consisted of mouldboard ploughing of the soil up to 22 cm depth, followed by a disk harrow. The shallow tillage consisted of rototilling at 8–10 cm, when chisel tillage performed at 30-35 cm. Wheat was drilled during November 2003 and the following year vetch was drilled in December 2004. Maize was planted the following year of May 2005. The depth of planting was around 5 cm. The experimental design was a split-plot treatment arrangement with three replications of each tillage treatment plot. Plot dimensions for each tillage treatment were 6.10 m wide (eight crop rows) and 40 m long. Fertilizers were applied starting (in 2003) with the first crop (wheat) in the three tillage treatments, averaging 150 kg N ha^{-1} $year^{-1}$ and 50 kg P ha^{-1} $year^{-1}$, as urea and compound fertilizer. About two-thirds of the N and all the P fertilizer were placed with the seed as a compound fertilizer at an average rate of 50 kg N ha^{-1}, 50 kg P ha^{-1} and as urea at an average rate of 60 kg N ha^{-1}. The remaining N was broadcast in spring of the following year at the mid-tillering wheat stage as ammonium nitrate at a rate of 40 kg N ha^{-1}. Starter fertilizer was applied in a band at planting in all maize plots at a rate of 50, 50, and 0 kg ha^{-1} in the form of a compound of N, P, and K, respectively. No application of fertilizer was done after planting. In this region, the maize crop needs between 150 to 200 kg N ha^{-1} of fertilizer during the growing period. Previous studies in this region indicated that a preceding vetch crop could provide between 110 to 200 kg N ha^{-1} to the subsequent crop (Ozpinar and Baytekin, 2006), therefore, maize probably had adequate N in the vetch-maize rotation, regardless of the management system.

Three plant samples per plot were taken in the summer of 2005, 2006 and 2007 at midseason. Each sample was a composite of 15 plants taken in the center of the plot. Each sample was separated into roots and aboveground material (stems, leaves, etc.), dried at 60 C, weighed, grounded, homogenized and a representative subsample, analyzed. For each sample, N was determined by the CHN analyzer (EuroVector, Euro-EA3000, Italy) using 1-1.5 mg of crop samples and S determined by CNS analyzer (LECO). The macro and micro elements (K, Mg, Ca, Na, B, Zn, Mn, Fe, Cu, Al, Ba, Cd, Co, Cr, Ni, Pb and Se,) were extracted with perchloric and nitric acids and determined using VARIAN ICP/AES. However, crop stems and roots in 2005 and some these in 2007 were not determined due to samples mistakenly being discarded before determining nutrients concentration.

Analysis of variance was performed for all response variables for a split-plot treatment arrangement using the procedures of the MSTAT-C . The ANOVA procedure was used to evaluate the significance of each treatment for data. Treatment means were separated by the least significance difference (LSD) test. All significant differences are reported at the 5% level.

RESULTS and DISCUSSION

The macro and micro nutrients concentration of roots and aboveground biomass are shown in Tables 1 and 2. In general, higher concentrations of macronutrients were found in aboveground biomass higher concentrations were found in roots. The exceptions were Ca and Na, those behavior resembled that of micronutrients in 2006 and 2007, and Mg, where low values prevented any meaningful comparison among plant components in 2006.

Table 1. Macronutrients concentrations (g kg^{-1}) in maize tissues in MT, ST and CT in a clay loam soil[a]

Components	Tillage	N*	K	S	Mg	Ca	Na
		2005					
Leaves	ST	20.8a	8.0a	1.5b	1.6a	5.0a	0.4a
	MT	25.0a	7.2a	2.7a	1.6a	6.3a	0.4a
	CT	24.7a	8.3a	2.6a	1.6a	8.1a	0.4a
		2006					
Leaves	ST	30.5a	11.2a	1.9a	1.6a	4.8b	0.6a
	MT	33.5a	11.4a	1.9a	1.6a	4.1b	0.4a
	CT	30.5a	13.2a	2.0a	1.6a	6.4a	0.4a
Stems	ST	10.4a	16.7a	1.1a	1.6a	7.4a	0.2a
	MT	7.9b	0.1b	1.5a	1.6a	7.4a	0.2a
	CT	8.6b	14.4a	1.2a	1.6a	8.2a	0.2a
Roots	ST	-	6.9a	1.5a	1.6a	24.6a	1.0
	MT	-	10.1ab	1.3a	1.6a	16.0b	1.0a
	CT	-	14.5a	1.3a	1.6a	18.6b	1.1a
		2007					
Leaves	ST	28.5a	18.7a	3.0a	3.3a	20.6a	0.4a
	MT	26.8a	21.4a	2.1a	2.3a	18.4a	0.3a
	CT	23.6a	17.1a	2.2a	2.8a	19.1a	0.5a
Stems	ST	-	15.4a	1.6a	2.8a	17.7a	0.2a
	MT	-	17.4a	1.6a	2.6a	18.2a	0.5a
	CT	-	13.0a	1.6a	3.1a	19.3a	0.3a
Roots	ST	11.7a	9.8ab	2.3a	5.7a	46.7b	2.2a
	MT	10.6a	10.4a	2.0a	5.9a	53.3a	1.8a
	CT	12.4a	6.1b	1.7a	5.6a	44.7b	1.4a

[a] Means with different letter in each column are significantly different between treatments at (P <0.05)

Concentration of the studied macronutrients, N, K and S showed no differences between tillage treatments in leaves in both 2006 and 2007 growing seasons, while S was found significantly lower under ST in 2005. Conversely, root showed some differences according to the tillage treatments; higher contents of K in CT in 2006 when lower contents of K was found in CT in 2007 (Table 1). Limited differences found in macronutrient concentrations in three treatments could be explained by the nutrient addition from green fertilization by cover crop before maize panting. In general terms, the N and S concentrations for aboveground and roots under three tillage treatments were higher than that showed by Lavado et al. (2001), particularly for leaves and stems, but MT was associate with a higher maize leaf N in comparison with the roots, while for micronutrients concentration compared with that of the leaves in the ST and CT in 2005 and 2006. This might indicate lower nitrogen immobilization and higher mineralization with the MT than with ST and CT. The K concentration was similar for each tillage treatments in 2005 and 2006 and higher for MT comparing ST and CT in 2007. In addition, K was found higher according to results found by Lavado et al. (2001).

In general, concentration of the seven studied micronutrients and some of these known as heavy metals, B, Zn, Mn, Fe, Cu, Se and Al, also showed no differences between tillage treatments in both aboveground and root material (Table 2), exception of the Mn in 2006 that CT was received uptake more Mn from soil to leaves. Conversely, ST was taken more Fe and Al from the soil to leaves comparing MT in 2006. According to some early researchers (Pais and Benton-Jones,1997), in considering all experimental year, the concentrations of B, Zn and Cu in maize leaves and stems were lower with 10-50, 20-100 and 0-30 mg kg^{-1}, respectively, than normal range 7-75, 15-150 and 3-40 mg kg^{-1}, respectively. However, these results showed that B, Zn and Cu concentration was higher under ST comparing MT. This implies that there could be a relationship between both Cu and Zn behaviour in soils and its uptake and accumulation in maize tissue. In roots the concentration of B, Zn, Cu and the rest of other micronutrients was registered higher values than aboveground in all experimental years, but there are no significant differences between treatments, except Al in 2006 and 2007 and Fe in 2006. The concentration of Al was higher under ST and MT for roots in 2006 and 2007, respectively, while it was increased its concentration in aboveground for ST in 2007. The concentration of Cd did not vary among tillage treatments in all experimental years according to aboveground biomass and roots, while the determined Cd contents, particularly in leaves and stems were low with 0-0.80 mg kg^{-1} comparing normal range with 0.8-4.8 mg kg^{-1} (Fergusson, 1990). Cd was accumulated mainly in the roots, and small quantities of Cd were transferred to the leaves and stems in 2006. Ni accumulated more in roots of maize and was registered no difference between treatments. Se showed similar results to other micronutrients behaviour between tillage treatments that its accumulation higher in roots than leaves and stems were higher 70-224 µg kg^{-1} than the nutritional level of Se for animals and also humans ranging from 50 to 100 µg kg^{-1} and its concentration below that range might cause severe deficiency diseases (Gissel-Nielsen et al., 1984). In all experimental years, only aboveground biomass Se concentration varied 0.0007-0.0099 g kg^{-1}, which covers a wide range very to sufficient in terms of the nutritional requirement because maize leaves and stems biomass were consumed by animal as nutrient in this region, while its grain was used for human food.

Table 2. Micronutrients and heavy metals concentrations (mg kg^{-1}) in maize tissues in MT, ST and CT in a loam soil clay[a]

Components	Tillage	B	Zn	Mn	Fe	Cu	Al	Ba	Cd	Co	Cr	Ni	Pb	Se
							2005							
Leaves	ST	0.03a	0.05a	0.06b	0.19a	0.02a	0.46a	0.032a	0.0001a	0.0001a	0.0013a	0.0017a	0.0035a	0.0066a
	MT	0.03a	0.05a	0.08b	0.20a	0.02a	0.42a	0.031a	0.0002a	0.0002a	0.0015a	0.0017a	0.0029a	0.0042b
	CT	0.02a	0.05a	0.10a	0.16a	0.02a	0.49a	0.032a	0.0001a	0.0001a	0.0014a	0.0013a	0.0035a	0.0072a
							2006							
Leaves	ST	0.02a	0.05a	0.07b	0.20a	0.01a	0.63a	0.020b	0.0001a	0.0001a	0.0021a	0.0019a	0.0021a	0.0026b
	MT	0.02a	0.03b	0.07b	0.16a	0.01a	0.55a	0.018b	0.0001a	0.0003a	0.0012b	0.0012b	0.0022a	0.0060a
	CT	0.02a	0.04b	0.12a	0.19a	0.01a	0.64a	0.023a	0.0002a	0.0002a	0.0010b	0.0018a	0.0014b	0.0007c
Stems	ST	0.01a	0.02a	-	0.07a	0.01a	0.27a	0.014b	0.0001a	0.0004a	0.0006a	0.0012a	0.0024a	0.0040b
	MT	0.01a	0.02a	-	0.07a	0.00b	0.26a	0.022a	0.0003a	0.0001a	0.0007a	0.0012a	0.0024a	0.0099a
	CT	0.01a	0.03a	-	0.08a	0.01a	0.26a	0.021a	0.0000b	0.0005a	0.0006a	0.0014a	0.0020a	0.0058b
Roots	ST	0.05a	0.05a	-	6.90a	0.01a	11.07a	0.175a	0.0008a	0.0002c	0.0216b	0.0375a	0.0069a	0.0959a
	MT	0.00b	0.04a	-	3.56b	0.01a	6.38b	0.089b	0.0006b	0.0006b	0.0141b	0.0253b	0.0024b	0.0440c
	CT	0.03a	0.05a	-	4.60b	0.01a	7.45b	0.106a	0.0005b	0.0009a	0.0190a	0.0314a	0.0018b	0.0615b
							2007							
Leaves	ST	0.04a	0.04a	0.09a	0.67a	0.01a	1.18a	0.012b	-	-	0.0297a	-	-	-
	MT	0.03a	0.04a	0.07a	0.26a	0.01a	0.82b	0.305a	-	-	0.0034b	-	-	-
	CT	0.03a	0.03a	0.06a	0.29a	0.01a	0.81b	0.009c	-	-	0.0097b	-	-	-
Stems	ST	0.01a	0.05a	0.03b	0.22a	0.01a	0.83a	0.013a	-	-	-	-	-	-
	MT	0.01a	0.03b	0.10a	0.22a	0.01a	0.78a	0.012a	-	-	-	-	-	-
	CT	0.01a	0.04b	0.03b	0.31a	0.01a	0.82a	0.013a	-	-	-	-	-	-
Roots	ST	0.02a	0.08a	0.43a	13.14a	0.03a	18.12b	0.090a	-	0.0097a	0.0663a	0.0745a	-	0.1577b
	MT	0.01b	0.10a	0.51a	15.31a	0.03a	23.76a	0.110a	-	0.0111a	0.0872a	0.0838a	0.0067a	0.2243a
	CT	0.01b	0.07a	0.46a	13.34a	0.02a	17.74b	0.100a	-	0.0089a	0.0769a	0.0840a	0.0021b	0.1649b

[a] Means with different letter in each column are significantly different between treatments at (P <0.05)

CONCLUSION

Tillage treatments influenced more the plant accumulation of macronutrients than micronutrients. Compared all elements according to tillage treatments, N, K, S, Fe and Al showed a significant relationship between their accumulation in aboveground material and their accumulation in roots when the rest of other elements usually did not show a significant differences between tillage treatments. The concentration of all elements in this study was showed normal range given by other studies, exception of the Se which results higher amount of content in both aboveground and roots material.

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REFERENCES

Arvidsson, J., 1999. Nutrient uptake and growth of barley as affected by soil compaction. Plant Soil. 208, 9-19.

Carter, M.R., Gupta, U.C., 1997. Micronutrient concentration in barley and soybean under minimum tillage on podzolic soils in a cool climate. Acta Agric. Scand. B. 47, 7-13.

Gissel-Nielsen, G., Gupta, U.C., Lamand, M., Westermarck, T., 1984. Selennium in soils and plants and its importance in livestock and human nutrition. Adv. Agron. 37, 397-460.

Hargrove, W.L., 1985. Influence of tillage on nutrient uptake and yield of corn. Agron. J. 77, 763-768.

Lavado, R.S., Claudia, A.P., Alvarez, R., 2001. Nutrients and heavy metals concentration and distribution in corn, soybean and wheat as affected by different tillage systems in the Argentine Pampas. Soil & Till. Res. 62, 55-60.

Lipiec, J., Spepniewski, W., 1985. Effects of soil compaction and tillage systems on uptake and losses of nutrients. Soil & Till. Res. 35, 37-52.

Ozpinar, S., Baytekin. H., 2006. Effects of tillage on biomass, roots, N-accumulation of vetch (*Vicia sativa* L.) on a clay loam soil in semi-arid conditions. *Field Crops Res.* 96, 235-242.

Pais, I., Benton, Jones, J.J., 1997. The Hanbook of Trace Elements. St Lucie Press, Florida, USA.

Shierlaw, J., Alston, A.M., 1984. Effect of soil compaction on root growth and uptake of phosphorus. Plant Soil. 77, 15-28