LIMING OF ACID SOILS. I. INFLUENCE ON WHEAT YIELD AND AVAILABILITY OF SOIL NUTRIENTS

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ABSTRACT
With a two year field experiment the influence of liming of strongly acid soils on wheat yield and on the availability of soil nutrients were studied. The results showed that liming increased soil pH and decreased exchangeable Al and available Fe and Zn. Wheat uptake of Mn was decreased, while P and Cu uptake were increased. Wheat biomass (hay plus seed) production and grain yield were also significantly increased.

KEYWORDS
Acid soils, liming, wheat, soil nutrients, availability

INTRODUCTION
Soil acidity is a serious constraint to crop production in many regions of the world (Hue, 1992). It is caused by several factors such as leaching of basic cations, in areas where rainfall exceeds evapotranspiration, removal of basic cations by crops, decomposition of soil organic matter and continuous use of acid-forming fertilizers (Mohebbi and Mahler, 1988). Strongly acid soils are usually infertile because of the possible aluminum (Al) and manganese (Mn) toxicities and calcium, magnesium, phosphorus (P), and molybdenum deficiencies. Soil acidity is corrected by liming, e.g. application of materials whose Ca and Mg neutralize acidity. This involves lowering of toxic elements (Al and Mn) and increase in the availability of other nutrients. These materials include limestone, quicklime, hydrated lime, various byproducts etc. (Barber, 1984).

In Western Greece, where rainfall is high, there are large areas of strongly acid soils. Besides the climatic factors, the continuous application of acid-forming fertilizers substantially contribute to the creation of the acidity of these soils. Productivity of these soils has been dramatically decreased and they are now used as grasslands for cattle and sheep production in the area. Such areas may become very productive by liming. The purpose of this study was to investigate the influence of liming on the wheat yield and on the availability of soil nutrients under field conditions.

MATERIALS AND METHODS
Two liming materials were investigated on a strongly acid Aquic Haploxeralf from Central Greece: quicklime (QL), which is burned limestone, and refuse lime (RL) from a sugar beet factory near Larissa, Central Greece. The experimental design was completely randomized blocks with the following treatments:
C, control, without liming material.
RL1, refuse lime 7500 kg ha^{-1},
RL2, refuse lime 15000 kg.ha^{-1},
RL3, refuse lime 3000 kg ha^{-1},
QL1, quicklime 2500 kg ha^{-1},
QL2, quicklime 4500 kg ha^{-1}, and
QL3, quicklime 6500 kg ha^{-1}.

The experimental plots were 4.0 x 4.0 m and all the treatments were replicated four times. Fertilization was the same for all treatments and was consisted of 300 kg ha^{-1} ammonium superphosphate and 300 kg ha^{-1} calcium nitrate ammonia. The first type of fertilizer was basically applied before planting and the second one was applied on the soil surface in the spring. Liming materials were applied in the beginning of October, 1995 and the field was planted with wheat (*Triticum vulgare* L) in the beginning of the following December. The same experimentation was repeated in the next year 1996. The crop was harvested in the middle of the following June.

At the boot stage, plant samples, consisting of whole plants, were collected from each plot and after the required preparation (Jackson, 1958), were analyzed for P, Mn, Zn, Cu, and Fe. Composite soil samples were also collected from each plot, which after air drying, crushing and sieving to pass through a 2 mm sieve, were analyzed for pH (in 1:1 soil:water suspension), exchangeable Al, after extraction with 1M KCl, P-Olsen and for the metals Fe, Zn, Mn, and Cu after extraction with 0.05 M DTPA (pH 7.3) solution. All the methods used are described by Page (1982).

RESULTS AND DISCUSSION
The soil was sandy loam in its texture, strongly acid (pH 4.2), with low cation exchange capacity [7.5 cmol(+) kg^{-1}], high exchangeable Al (95 mg kg^{-1} soil), low exchangeable K (70 cmol kg^{-1}), low organic matter content (1.0 %) and high available P (26 mg kg^{-1}), and metals.

Liming significantly affected soil pH, exchangeable Al and available Zn and Fe (Table 1), while it had no significant effect on available P, Cu and Mn (data not presented). Soil pH was increased from 4.2 to near 7.0 and remained stable for the two years of experimentation. Exchangeable Al was decreased from 98.1 mg kg^{-1} to almost zero in the treatments RL3 and QL3. Available Fe and Zn were also decreased from 221 to 49 and from 2.75 to 1.6 mg kg^{-1} respectively. Iron and Zn were strongly correlated with pH (r=-0.82*** and r=-0.59**) respectively. The increase in soil pH resulted in a significant decrease in Mn concentration and in an increase in P and Cu concentrations in wheat tissue (Table 1). Similar results on the influence of soil pH on the metals investigated here were reported by several workers (Schwab et al., 1990; Adams, 1984; Graham and Nambiar, 1981).

Biomass (hay plus seed) production and seed yield in both years of experimentation were significantly increased because of the liming (Table 2). Production in the year 1995 was greater than 1996 because of the more favorable weather conditions that occurred that year. Seed yield was strongly correlated with soil pH (R^2=0.86***).

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Table 1
The influence of liming on some soil properties and uptake of some nutrients by wheat

Treament	pH		Soil concentration			Leaf concentration		
			Al	Zn	Fe	P	Mn	Cu
	1995	1996	mg kg^{-1} soil			mg kg^{-1} dry matter		
C	4.2a	4.3a	98.1c*	2.7c	221.2b	2622a	1447c	7.7a
RL1	5.9bc	5.7b	1.6a	2.6bc	98.3a	4439cd	827b	8.5a
RL2	6.5c	6.6c	8.cab	1.8ab	52.9a	4554d	472a	9.75ab
RL3	6.9c	7.0c	0.4a	1.5a	53.7a	4648d	635ab	8.75a
QL1	5.3ab	5.5b	28.4b	2.0abc	111.2a	3810b	720ab	9.0a
QL2	6.1bc	5.2b	7.4a	1.9abc	65.3a	3950bc	683ab	8.75a
QL3	6.2bc	6.4c	0.9a	1.7ab	49.3a	3949bc	514ab	13.5b

*: Values on the same column with different subscripts are different, P<0.05, according to LSD test.

Table 2
The influence of liming on the wheat biomass and seed yield

Treatments	Biomass	Seed yield	Biomas	Seed yield
	kg ha^{-1}			
	1995		1996	
C	5240a	1650a	5490a	1140a
RL1	11080b	4460bc	7330b	2840b
RL2	10620b	4490bc	7640b	3140b
RL3	11370b	4700bc	7460b	3020b
QL1	10670b	4270b	7230b	3060b
QL2	11370b	4600bc	7530b	3340b
QL3	11500b	4970c	7950b	3140b

*: Values on the same column with different subscripts are different, P<0.05, according to LSD test.