INVESTIGATION TO DETERMINE FERTILITY STATUS IN A SEMI-ARID ENVIRONMENT OF AGRICULTURAL AREAS, TURKEY

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ABSTRACT

This research was conducted on the high quality agricultural land of the district of Alaşehir in the Manisa region of Turkey, where total agricultural land covers 457,699 ha. Soil samples, representing a total area of 8400 ha, where mostly grapes, cherry and vegetables are grown, were taken within the depths of 0-30 and 30-60cm. Soil samples were collected from 145 different points in the sampled area. Two samples were taken at every point, making a total of 290 soil samples, which were analyzed to determine their physical and chemical properties. The results show the productivity characteristics of these agricultural soils. The results indicate that the soils are highly calcareous, with high pH, low levels of organic matter phosphorous and potassium. The sampled soils are deficient in zinc and iron (approximately 70-78% of the samples), manganese (50-55% of the samples), but have an excess copper content (approximately 95% of the samples) and excess boron content (approximately 50% of the samples).

Keywords: *Soil analyzes, soil fertility, Alaşehir, Manisa*

INTRODUCTION

Turkey is a peninsula located in the northern hemisphere between 36-42^{o} north latitude and 26-45^{o} east longitude surrounded by the Mediterranean Sea in the south, by the Aegean Sea in the west, and by the Black Sea in the north. it also has been the high agricultural production potential, and large areas of sustainable land. Soil fertility embraces all those factors that contribute to the long term sustainable productivity of soil. Some of the features of a fertile soil organic matter content, balanced nutrient and water availability, good structure and other factors. Continual use means the uniformity and compositional balance of soils must be protected. Maintaining soil productivity during and after production is important in agriculture.

The Manisa region covers 1800,080 ha, 22·3% of which (457,699 ha) is used agriculture. Alaşehir occupies 27,490 ha of this area. Vineyards occupy 18,400 ha, cherry 1500 ha, fruit growing 1602 ha, 1783 ha vegetables, 1850 ha tobacco, olives 635 ha, and cotton 120 ha [1]. The region has a rich variety of crops, mainly grape, but also appear, chestnut, cherry, apple, tomato, cucumber, watermelon, bean and spinach.

This study aims to determine the soil limitations of the area, the effects of environmental factors on these limitations and how agriculture can be sustainable in the area.

EXPERIMENTAL

This study was carried out in an area between Alaşehir and Sarıgöl, which comprises 6·2% of Manisa's agricultural land. This area is known for its rich variety of agricultural production. The total annual rainfall in the area is 566·1mm. Most rain falls in October, November, December, January and February (total rainfall=364·1mm). Other climatic factors are shown in Table 1[2]. The dry season occurs during June, July, August and September (total rainfall=24·8mm). The highest temperatures are experienced in June, July, August and September (mean temperature is over 20°C). The coldest period (mean temperature is below

10˚C) runs from December to March[2,3]. The soil parent materials are sandstones, siltstones, tufa and limestone[3]. The slope of the research area is between 0·2% and 0·6%, and mean height above sea level is 189m.

A total of 290 soil samples (145×2) were taken from 0-30 and 30-60cm depths in 145 randomly selected fields with various representative agricultural land uses[4]. The particle size distribution of each sample was determined by the hydrometer method, pH in a soil: water (1:2·5) mixture with a pH meter, $CaCO_3$% with a Scheibler calcimeter[5], CEC (meq $100g^{-1}$), potassium and sodium (meq $100g^{-1}$) with 1N ammonium acetate (pH 7)[6,7,8], available phosphorus (P_2O_5) by the Olsen method and Fe, Cu, Zn and Mn with 0·05M DTPA-TAE by AAS equipment[4,8]. Boron was analyzed[9]. Correlations between the various soil properties of correlations were determined to draw meaningful results.

Table-1: Climatic factors of the research area

Climatic factors	Minimum	Maximum	Mean	Total
Temperature (°C)	4·9	28·4	15·3	
Rainfall (mm)	3·1	163·8		566·1
Evaporation (mm)	22·4	197·9		127·6
Cloudiness (0-10)	1·5	5·9	4·1	
Sunshine hours (h, min)	03:50	12:38	07:45	
Sunshine density (cal cm^{-2} min^{-1})	134·11	522·32	345·59	
Wind velocity (m s^{-1})	1·4	3·8	2·9	
Min. temp. above soil (°C)	2·5	17·4	9·3	
Temp. at 5 cm soil (°C)	6·3	32·8	18·1	
Temp. at 10 cm soil (°C)	6·7	21·9	17·6	
Temp. at 20 cm soil (°C)	6·4	27·4	17·2	
Temp. at 50 cm soil (°C)	7·8	26·1	16·8	
Average of relative humidity (%)	40·0	69·0	54·0	
Number of freezing days (number)	0.0	0·7		3·2
Number of hoar frost days (number)	0.2	3·1		14·8

RESULTS AND DISCUSSION

Minima, Maxima and mean values for various soil properties are shown in Table 2. The results are classified in Table 3, and correlations between properties for the 0-30 cm and 30-60 cm depths are shown in Table 4.

Table 3 shown that most soils are classified as sandy loams (38·5%). Only 2·8 % of the samples are classified as loams. Loamy sands and sandy clay loams each make up about 23·6% of all samples. This results that most soils are loamy in texture. The porosity, organic matter content, water-holding capacity, infiltration rate, micro-biological activity, airing and nutrient element capacity of the loamy soils make them relatively fertile for agricultural production[11,12].

At both depths, soil pH was mostly classified as ‘slightly alkaline’ (pH 7·5-8·5). A few samples were classified as ‘moderately acidic’ (pH 4.5-5.5). Thirty per cent of the soils were classified as ‘neutral’ (pH 6·5-7.5)[4,5]. In fact, 91·1% and 90·6% of the samples at 0-30 cm and 30-60 cm depths respectively fall between pH 6·5 and 8·5. This range of pH is associated with soils highly suited to agriculture, all other factors being equal[10,11].

This clues that most of the region’s soils have insufficient organic matter and therefore should be fertilized with organic fertilizers, to increase fertility and perevent physical degradation[10]. Most soils need to be fertilized with 30-40 ton ha^{-1} of organic fertilizer every 2-3 years to ensure productivity and yield levels according to the Agriculture Ministry of Turkey[12].

Thirty per cent of the soils at both depths are weakly calcareous (<1% $CaCO_3$). At this level, cultivation can be practised without intervention[4,5]. However, 24·7%-26·3% of the soils are classified as 'calcareous' (1-5% $CaCO_3$) and 20·3-17·5% as 'moderately calcareous' (5-15% $CaCO_3$). These soils may require acidifying fertilizers[4,11,12]. Highly calcareous (15-25%) in 24·4- 20·4 and very highly calcareous (>25%) soils were found in 4·0-0·4% of samples at both depths. In these areas the excessive calcareous content of the soils must be balanced by applying acidifying fertilizers[4,11,13].

Exchangeable Na (meq $100g^{-1}$) was classed as 'low' (0·09-0·5 meq $100g^{-1}$)in 95·6% of the samples from 0-30 cm, and in 97·5% of those from the 30-60cm depth. It was 'high' (0·5 $meq100g^{-1}$) in 4·4% of the samples from 0-30 cm, and in 2·5% of the samples the 30-60 cm depth. There are a few salinity problems in the region, which benefits agricultural production, but it should be watched out of water quality[5].

Cation exchange capacity (CEC) did not vary with depth. At both depths, 22·1% of the samples had CEC <10meq $100g^{-1}$, approximately 56·9% had CEC 10-20meq$100g^{-1}$, 15·4% had CEC 20-30 meq $100g^{-1}$and 5·6% had CEC=>30meq100^{-1}. Available phosphorus was classed as 'very low' (<30kg ha^{-1}) and 'low' (30-60kg ha^{-1}) in 56% of the sampled soils for both depths. This clues that 56% of the area needs regular phosphorus fertilization. Use of phosphorus fertilizers compared to other nutrients requires more knowledge and care with respect to the application technique, application depth, from, amount and time.

Table-2: Physical and chemical properties

Properties	0-30 cm depth			30-60 cm depth		
	Min	Max	Mean	Min	Max	Mean
pH 1:2·5	6·5	8·2		6·4	8·1	
Organic matter (%)	0·60	2·40	1·45	0·40	1·25	0·90
$CaCO_3$ (%)	0·20	25·20	9·75	0·15	20·75	8·49
CEC (meq 100 g^{-1})	4·55	39·40	18·20	5·20	18·20	18·35
Na (meq 100 g^{-1})	0·10	0·55	0·18	0·10	0·15	0·40
K_2O (kg ha^{-1})	10·5	48·4	19·8	10·4	45·0	18·80
P_2O_5 (kg ha^{-1})	3·40	15·0	5·1	3·10	14·5	4·90
Fe (p.p.m.)	1·20	25·0	5·3	0·9	24·3	49·80
Mn (p.p.m.)	3·00	10·4	7·2	2·8	9·4	6·50
Zn (p.p.m.)	0·40	1·7	0·7	0·3	1·5	0·70
Cu (p.p.m.)	0·20	1·19	0·8	0·20	1·05	0·75
B (p.p.m.)	0·5	4·2	2·4	0·5	4·3	2·25
Sand (%)	34·50	91·2	65·50	34·50	91·3	64·25
Silt (%)	4·80	39·4	19·30	5·40	38·2	18·25
Clay (%)	3·85	40·3	17·30	5·30	37·9	11·48

The plant availability of P when applied by spreading or mixing will be limited in heavy soils due to the high adsorbtion of P onto soil particles[10].

Available potassium were classed as 'low' (<200 kg ha^{-1}) in 49·4% and as 'moderate' (200-300 kg ha^{-1}) in 20·6% of the sampled soils for both depths. The proportion of the soils with 'sufficient' (300-400 kg ha^{-1}) in 22·8% or 'high' (>400 kg ha^{-1}) in 7·2% of the sampled soils for both depths. As a results, levels of potassium, which will therefore need K fertilizer was about 50% of the sampled soils for both depths (Table 3). These low levels of potassium can be explained as a result of climate, geology, dominating clay minerals and mineralogical structure[7,18]. However, despite these high levels of K, its availability to plants is limited, as K tends to be lost by leaching and adsorption[10,11,14].

Table-3: Classification of the soil samples by physical and chemical properties

Property	Depth	Sand	Loam	Sand-load	Loam-sand	Sand-clay-loam	Clay -loam
Particle size distribution	0-30 cm	6·4%	2·8%	38·5%	23·6%	25·5%	3·2%
	30-60 cm	5·0%	1·8%	37·4%	28·6%	26·3%	0·9%
pH 1:2·5	Depth	Strongly acid (<4·5)	Moderately acid (4·5-5·5)	Slightly acid (5·5-6·5)	Neutral (6·5-7·5)	Slightly alkali (7·5-8·5)	Strongly alkali (>8·5)
	0-30 cm	0·0%	0·0%	8·9%	%38·1	53·0%	0·0%
	30-60 cm	0·0%	0·0%	9·4%	%33·5	57·1%	0·0%
Organic matter	Depth	Very low (<1%)	Low (1-2%)	Moderate (2-3%)	Sufficient (3-4%)		High (>4%)
	0-30 cm	39·5%	55·5%	5·0%	0·0%		0·0%
	30-60cm	44·2%	54·0%	1·8%	0·0%		0·0%
$CaCO_3$ (%)	Depth	Weakly calcareous (<1%)	Calcareous (1-5%)	Moderately calcareous (5-15%)	Highly calcareous (15-25)		Very highly calcareous (>25%)
	0-30 cm	34·4%	24·7%	20·3	24·4%		0·2%
	30-60 cm	35·8%	26·3%	17·5	20·4		-
Na (meq 100 g^{-1})	Depth	Very low (0-0·09)			Low (0·09-0·5)		Excess (>0·5)
	0-30 cm	0·0%			98·0%		2.0%
	30-60 cm	0·0%			100·0%		0·0%
CEC (meq 100 g^{-1})	Depth	(<10)	(10-20)	(20-30)		(30<)	
	0-30 cm	22·1%	56·9%	15·4%		5·6%	
	30-60 cm	23·4%	57·3%	16·7%		2·6%	

Available P_2O_5 (kg ha^{-1})	Depth	Very low (<3)	Low (3-6)	Moderate (6-9)	High (9-12)		Very high (>12)
	0-30 cm	24·3%	55·50%	19·7%	1·0%		0·0%
	30-60 cm	23·8%	57·80%	17·0%	1·4%		0·0%
K_2O (kg ha^{-1})	Depth		Low (<20)	Moderate (20-30)	Sufficient (30-40)		High (>40%)
	0-30 cm		49·4%	20·6%	12·8%		7·2%
	30-60 cm		46·0%	24·3%	222%		7·5%
Fe (p.p.m.)	Depth	Deficient (<2)		Marginal (2-4·5)		Adequate (>4·5)	
	0-30 cm	24·0%		46·8%		29·2%	
	30-60 cm	26·5%		48·3%		25·2%	
Zn (p.p.m.)	Depth	Deficient (<0·5)		Marginal (0·5-1·0)		Adequate (>1·0)	
	0-30 cm	48·7%		29·8%		21·5%	
	30-60 cm	50·2%		28·2%		21·6%	
Cu (p.p.m.)	Depth	Adequate (≤0·2)				Excess (>0·2)	
	0-30 cm	0·4%				99·6%	
	30-60 cm	1·8%				98·2%	
Mn (p.p.m.)	Depth	Insufficient (<3)		Marginal (3-5)		Excess (>5)	
	0-30 cm	25·8%		29·9%		44·3%	
	30-60cm	24·1%		25·2%		50·7%	
B (p.p.m.)	Depth	Slightly effect (1·0-1·5)	Effect (1·5-2·5)	High effect (2·5-4·0)			
	0-30 cm	48·7%	29·8%	21·5%			
	30-60 cm	50·2%	28·2%	21·6%			

Table-4: Coefficients of analysed criteria (r)

property	Org.Mat (%)	$CaCO_3$ (%)	CEC (meq $100g^{-1}$)	K (meq $100g^{-1}$)	Na (meq $00g^{-1}$)	Fe (p.p.m.)	Mn (p.p.m.)	Zn (p.p.m.)	Cu (p.p.m.)	B (p.p.m.)	P_2O_5 (kg ha^{-1})	Sand (%)	Silt (%)	Clay (%)
0-30 cm depth														
pH 1:2·5	0·418**	0·614**	0·521**	0·585**	0·231**	-0·812**	-0·817**	0·031	0·032	-0·817**	-0·421**	-0·654**	0·543**	0·645**
Org·mat		0·033	0·537**	0·473**	0·212*	-0·322**	-0·258**	0·279**	0·911	-0·258**	-0·369**	-0313**	0·243*	0·462**
$CaCO_3$			0·311	0·543**	-0·104	-0·355**	-0·460**	-0·122	0·045	-0·460**	-0·321**	-0·418**	0·478**	0·345**
CEC				0·533	0·411**	-0·516**	-0·396**	0·269**	0·234*	-0·396**	-0·611**	-0·621**	0·290**	0·743**
K					0·063	-0·477**	-0·473**	0·164	0·134*	0·473**	-0·328**	-0·542**	0·465**	0·611**
Na						-0·135*	-0·135	0·119	0·196*	0·135	-0·213	-0·221**	0·079	0·424**
Fe							0·029	-0·151	-0·025	0·933**	0·308**	0·573*	-0·494**	-0·529
Mn								0·279**	0·279	0·419**	0·279**	0·238**	-0·467**	-0·354**
Zn									0·028	0·606**	0·245**	0·537**	-0·524**	-0·532**
Cu										0·712**	0·105	-0·142	-0·113	0·345*
B											0·517**	-0·311**	0·217	0·362**
Sand												0·423**	0·722*	-0·747**
Silt													0·412**	-0·747**
Clay														0·463**
30-60 cm depth														
pH 1:2·5	0·389**	0·523**	0·411**	0·592**	0·345**	-0·832**	-0·754**	0·231	0·015	-0·781**	-0·456**	-0·612**	0·502**	0·549**
Org·mat		-0·067	0·589**	0·554**	0·362**	-0·368**	-0·234**	0·398**	0·235**	-0·278**	-0·389**	-0·463**	0·315	0·507**
$CaCO_3$			0·437*	0·418**	-0·323*	-0·324**	-0·367**	-0·146	-0·278**	-0·260**	-0·374**	-0·394**	0·504**	0·231**
CEC				0·542**	0·354**	-0·423**	-0·329**	0·147	0·342**	-0·596**	-0·394**	-0·792**	0·452**	0·723**
K					0·122	-0·479**	-0·450**	0·301**	0·137*	0·473**	-0·256**	-0·512**	0·367**	0·608**
Na						-0·245**	-0·223*	0·223	0·112	0·335	-0·065	-0·212**	0·044**	0·329**
Fe							0·943**	-0·269**	0·101	0·812**	0·339**	0·489**	-0·371**	-0·398**
Mn								-0·145	0·154	0·680**	0·123	0·453*	-0·354**	-0·353**
Zn									0·065	0·712**	0·224**	-0·063	0·009	0·101
Cu										0.523	-0·028	-0.076	-0·162	-0·321
B											-0·087	-0·201*	0·154	0·243*
Sand												0·309**	-0·120	-0·365**
Silt													-0·743**	-0·548**
Clay														0·132**

*P<0·05.
**=P<0·01.

Because of the intensive agriculture of the region, continuous fertilization by sprayers or drip irrigation has been used to maintain productivity. The solutions used are NPK rich, but deficient in microelements[12,15]. Indeed, there are a few symptoms of plant NPK deficiency in the area. Liquid NPK application in the organic matter deficient soils (Table 3) can supply enough N and P, and enhance K.

Fe (p.p.m.) was classed as ‘deficient’ (<2 p.p.m.) in 24%, ‘marginal’ (2-4.5 p.p.m.) in 46.8 %, and ‘adequate’ in 29.2% (>4.5 p.p.m.) of the soils[17]. In other words, 76.1% of the sampled soils can be considered as deficient in Fe and may need Fe-fertilizing, depending on the crops to be cultivated[16,17].

Zinc (p.p.m.) was also found to be ‘deficient and marginal’ (≤1.0 p.p.m.) in 78.5 % of the soils of 0-30 cm depth, but sufficient (>1.0 p.p.m.) in 21.5%. At 30-60 cm depth, it was sufficient in 21.6% and insufficient in 78.4% of the samples[10,16].

Copper content of the soil was classified as ‘excessive’ (>0.2 p.p.m.) at both depths (99.6% at 0-30 cm and 98.2% at 30-60 cm depth) [10,17]. These results imply that the soils do not require copper supplements (Table 3).

Manganese content was found to be ‘marginal’ (3-5 p.p.m.) in 29.9 % of the surface soils, and in 25.2% of the deeper samples. Around 25.8% of samples from both depths were classed as having ‘insufficient’ Mn (<3 p.p.m.), whereas around 44.3% of the sampled had ‘excessive’ levels (>5 p.p.m.) [21]. Therefore, 45-50% of these soils may need Mn fertilization. Generally, foliar fertilization can be applied depending on type of crop. Boron content of the soil was classed as ‘Slightly effect’ (1.0-1.5 p.p.m.) in 48.7% of the samples from 0-30 cm, and in 50.2% of those from the 30-60cm depth. It was ‘high and very effect’ (1.5-4.0 p.p.m.) in 51.9% of the samples from 0-30 cm, and in 49.8% of the samples the 30-60 cm depth. It was determined that boron was in level which could effect as toxic in approximately 50% in the region. However, it should be watched out of water quality, used for irrigation[16].

The lack of Fe, Mn and Zn may be a result of application of microelement-deficient fertilizers (Table 3). Grapes grown in the area show symptoms of chlorosis, which indicates such deficiencies[11,13,14].

Copper preparations have been used against fungal diseases in the region, thereby increasing copper levels at both depths (Table 3).

Calcium ammonium nitrate is applied in the region at the during of the growing season[2]. Misapplication can cause an increase in calcareous levels, and in turn pH[5,11,12]. This relationship can be seen from the positive correlation between pH and calcareous levels (Table 4), where r= +0.614 at 0-30 cm soil depth, and r=+0.523 at 30-60 cm depth. As a result, phosphorous and microelements became unavailable to plants, as shown by the strong ($p<0.01$) negative correlation between soil pH and Fe, Mn, B and P_2O_5 (Table 4).Cu and NO_3 accumulation can lead to coastal pollution as drip irrigation used during the growing season flushes them out. At the end of the season (late autumn/winter) the increased rainfall of the typical Mediterranean climate washes the chemicals out to the sea. On-site, the soils are stripped of these trace elements at the start of the next growing season. There is no surface soil erosion in the area due to gentle slopes, drip irrigation and rich biomass, which all promote sustainable agriculture.

CONCLUSION

The results show that the soil textures of the Alaşehir-Sarıgöl region favour agricultural production, but pH and calcium carbonate (%) are fairly high. The soils are also insufficient in organic matter, phosphorous and potassium. Moreover, 70-78% of the area soils show Fe and Zn deficiency, 50-55% show manganese deficiency and 98% show excessive levels of copper and 50% show excessive levels of boron. For levels of boron should be watched out of water quality, used for irrigation. Although the soils are slightly alkaline, this can be overcome with respect to plant nutrition. High levels of lime and high pH can limit uptake of most microlements and phosphorous. It is advisable that solid fertilizers containing Fe, as well as N and P fertilizers are used. Foliar fertilizers containing Zn, Fe, and Mn can also be used after N-P fertilization. Chlorosis in grapevines in the research indicates significant Fe and Zn deficiencies. To regulate pH and avoid nutritional problems, it is recommended that 30-40 ha^{-1} of manure is applied every 2 years, and that acidifying chemical fertilizers (content S) are selected.

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