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EFFECT OF USING SEWAGE SLUDGE AND SEWAGE EFFLUENT ON SOME SOIL PROPERTIES OF CALCAREOUS SOILS.

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ABSTRACT

The area under investigation located in Ghmaza El-Kobrra South Helwan, and started reclaimed in 1985, using sewage sludge and sewage effluent to improve the soil properties. For this wedge, 25 profiles are representative four periods of treatment with sewage sludge and effluent as the following, first group 20 years, second group 15 years, third group 5 years and the fourth group zero years (virgin soils). The studies revealed that the morphological features changed from first group, to fourth group which clear from developing the morphological features as (colour, texture, structure, consistence, roots, boundary), The first group more developed than the second, third and fourth, respectively.

The physical properties as texture, Bd, Rd, Aw, Sp are changed from the first to the fourth group.
The changes in the physical properties could be refered to the effect of using sewage sludge and sewage effluent. The chemical properties such as pH, O.M %, $CaCO_3$, EC, CEC and gypsum content were changed with the period of application of sewage sludge and sewage effluent. It is clear that the effect of using sewage sludge and effluent on the chemical properties of the soils.

The soil fertility, such as macronutrients (NPK) in the first, second and third groups are higher than the critical levels of NPK, while macronutrients (NPK)) in the virgin soil lower than the critical levels of NPK.

The total content and bio-available heavy metals are higher in the treated soils than in the virgin soils. The value of the heavy metals is high in the first group and decreases in the second and third group. Two effects of using sewage sludge and effluent were obtained, the first effect which clear in improving the physical, chemical, and fertility properties of the soils, and the second effect which clear in increasing the content of heavy metals.

Keywords: Sewage sludge - Sewage effluent – Calcareous soil- Soil properties – Heavy metal- Morphological features.

INTRODUCTION

Sandy and calcareous soils are potentials for horizontal expansion and increasing the agricultural production in Egypt. Sewage sludge has been utilized as a source of nutrients and as an amendment for such soils (Epstein *et al.*, 1975; El-Keiy, 1983 and Abdel-Ghaffar *et al.*, 1985). A conclusion was drawn that the addition of sludge to sandy and highly calcareous soils improved their physical, chemical, and the productivity for the most crops.

El-Gendi *et al.*, (1997), El-Amir *et al.*, (1997), El-Motaium and Badawy (2002) and El-Gendi (2003), they found in their studies that amending soil with sewage sludge increased fine particles percentages and the increase become significant with increasing the rates and the period of application as the texture changed from sandy to sandy loam after seven years and to clay loam after twelve years of using sewage water. According to McBride (1995), Logan *et al.*, 1996 and Ibrahim (1998), of 60 ton/feddan applying sewage sludge to the soil decreasing the soil bulk density, they found also that the relation between the decreasing of the bulk density and the additions of sewage sludge is linear.

Logan *et al.*, (1996), Abdel-Naim *et al.*, (1997), and El-Amir *et al.*, (1997) the addition of sewage sludge to the soil improving the water holding capacity through effecting on the porosity and pore size distribution. Also Zaid and Askar (1987) Asker *et al.*, (1994) in their studies found that there is significant correlation between the rate of amending and both soil moisture capacity and the available water content in calcareous soils. Header (1987) and Awad (1991), concluded that applying sewage sludge at the rate of 100 and 150 g/kg soil improved soil properties, but has no adverse effect on soil salinity and the same result found after adding 60 ton/feddan. Awad (1991) and Malik *et al.*, (2000), found that the soluble salts are accumulated as a result of sludge application.

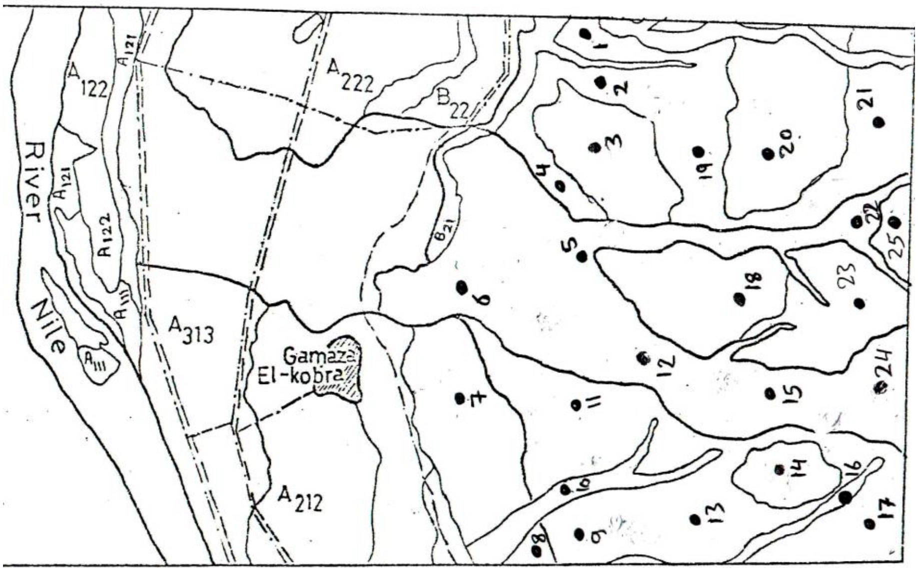
McBride (1995), El-Gendi *et al.*, (1997) and Badawy and Helal (1997), concluded that addition of sewage sludge increased the cations exchange capacity (CEC) and there is a linear relation between the application of sewage sludge and the increase in CEC. Abdel -Naim et al, (1997), El-Gendi *et al.*, (1997), Ibrahim (1998) and El-Motaium and Badawy (2002), mentioned in their studies that the addition of sewage sludge to the soil causes a decrease in the TCC in the soil which refered to the acid effect of decomposition of sewage sludge, decreased soil pH and this refered to the acidic effect of the decomposition of the sewage sludge, and increased the organic matter content specially in the surface layer than in the deep layers.

Badawy and Helal (1997), Abdel-Naim *et al.*, (1997) and Abdel-Aal (2001) mentioned that the application of sewage sludge which containing very low levels of heavy metals didn't causing any significant increase in heavy metals content while the sewage sludge which has high levels of heavy metals causing significant increase in heavy metals content in the soil. The levels of heavy metals in the soil affected by the number of years and rates of application, the movement of heavy metals in the soil profiles affected by the soil pH, soil texture, the water volume applied to soil through irrigation processes, the number of applied years, the amount of the added sludge, the soil organic matter, the relative mobility of the heavy metals, and the leaching ability of the heavy metals (El-Gendi *et al.*, 1997 and Camobreco *et al.*, 1996).

The present work aim to illustrate the effect of using sewage effluent and sewage sludge on some physical and chemical properties, fertility and heavy metals content of Ghmaza area in the Eastern Desert (calcareous soil).

MATERIAL AND METHODS

Map (1) shows the studied area which was started reclaimed at 1985 with the applying the sewage sludge and sewage effluent for irrigation. Twenty five soil profile were chosen to representative the variation in surface morphological features could be divided the soils of the area to four group, as the following: the first group which received the high amount of sewage sludge and using sewage effluent in irrigation for 20 years and represented by profiles 1, 2, 3, 5, 8, 10, 11, 12, 13, 14, 17, 18, 20 and 21, the second group, the addition of sewage sludge and irrigation by sewage effluent for 15 years and represented by profiles 7, 9, 15, 16, 19, while the third group received the sewage sludge and sewage effluent for 5 years and represented by profiles 4, 6, 25 and the fourth group still virgin with out reclaimed and represented by profiles 22, 23, 24 land use and the period of sewage sludge and sewage effluent application. The physiographic units were described according to Zinck and Valenzuala (1990). The soil profiles were morphologically investigated in the filed according to FAO (1990) and USDA (2002). Determination of textural classes, calcium carbonate, organic matter content, exchangeable cations and cation exchange capacity (CEC), soil reaction (pH), electrical conductivity (EC), soluble cations and anions in soil water extract (1:1) were determined according to USDA (2004). The total Fe, Mn, Zn, Cu, Pb and Cd were determined after vision with mixture of concentrated HNO_3, $HClO_4$ and H_2SO_4 (Hesse, 1971). The Bio-available heavy metals as Fe, Mn, Zn, Cu, Pb, and Cd were extracted using DTPA method (Lindsay and Norvell, 1978). Heavy metals were measured using Atomic absorption spectrophotometer.



Mineral N was extracted with 1.0 M KCl (1:5) and determined using the steam distillation methods to include NO_3 and NH_4 ions (Black, 1965), available P was extracted with 0.50 M $NaHCO_3$ solution according to Olsen *et al.*, (1954) and determined according to Watanabe and Olsen (1965), available K was extracted with 1.0 N ammonium actate solution and determined by flamephotometer (Richards, 1954).

The total heavy metals as Fe, Mn, Zn, Cu, Pb and Cd in sewage sludge were determined according to Hesse (1971). Heavy metals in sewage sludge, and sewage effluent mixed with industrial waste water were measured using Atomic absorption spectrophotometer.

RESULTS AND DCUSSION

The morphological features:

According to the period of using sewage sludge and effluent in the soil could be divided the soils to the first group using sewage sludge and effluent (20 years), second (15 years), third (5 years), and fourth (virgin soil) zero years. Table (1) showed that the land use ranged between cultivated with field crops, vegetables, orchards, vegetation for animals in the application soils while the virgin soil is barren. The ranged between dark in the first and second group, moderately dark in the third and light in the fourth group, which could be due to the effect of the sewage sludge and effluent. Structure ranged between very strong and strong sub angular blocky in the first group, moderately strong sub angular blocky in second group, slightly strong sub angular blocky in third group and single grins in the fourth group. The consistence ranged between very sticky, plastic, firm, hard in the first group, sticky moderately plastic, moderately firm, moderately hard in the second, moderately sticky, slightly plastic, friable, slightly hard in the third, and none sticky none plastic, loose in the fourth the group. The new formation changed from accumulated the residual of plants, sewage sludge, sewage effluents without humified on the surface layer in the first and second while its low in the third and there is no in the fourth group. There is a high content humified organo compound, hard nodules, concentrated of $CaCO_3$ and gypsum in the subsurface layer in the first and second groups while is low in the third and there is no in the fourth group. From the previous is clear that the morphological features more developed in the first, second while low in the third and their no developed in the fourth group could be due to the effect of the using sewage sludge and effluent to improved the properties of soil.

Physical properties:

From Table (2) the texture is clay, clay loam, sandy clay loam in the surface layer of the first group soil profiles, loamy in the second group soils profiles, sandy loam and loamy sand in the third group soil profiles, loamy sand and sandy in the fourth group soil profiles. The bulk density decreased in the surface layer and high in the deep layer in the first, second, and third group of soil profiles while is high in all the layers of fourth group of soil profiles. The bulk density changed from 1.2 g/cm^3 in the surface layers to 1.8

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g/cm^3 in the deep layers in the first, second and third groups while it is 1.8 g/cm^3 in all layers of fourth group (virgin soil). The real density take the same sequence of the bulk density and changed from 2.2 g/cm^3 in the surface layer to 2.56 g/cm^3 in the deep layers in the first, second and third while it is 2.56 g/cm^3 in all layers in fourth group soil profiles. The (Aw) and (Sp) take the same sequences following there are high in the surface layers and decrease with depth. The (Aw) changed from 80 % in the surface layers to 10 % in the deep layers and the (Sp) ranged between 90 % in the surface layers and 10 % in the deep layers in the first, second, while in the third changed from 20 % in the surface to 10 % in the deep layer for (Aw) and (Sp) and in the forth group (Aw) and (Sp) does not changed and equal 10 %. The variation in the physical properties could be referred to the application of sewage sludge and effluent is high in the surface layers of first, second groups profiles, while low in the third groups and there is no in the fourth groups.

Chemical properties:

From Table (3) the pH does not decrease than 7 because the $CaCO_3$ content of soil is high and buffered the pH in the soil. The organic matter content is high in the first and second groups ranged between 1.79 and 5.7 %, while in the third group ranged between 1.45 and 3.35 % and in the fourth group ranged between 0.45 and 0.93 % (in the surface layer). The variation in the organic matter could be due to the variation of the amount of sewage sludge and effluent and the period of application. The $CaCO_3$ content is high in all the profiles refered to the parent material and the variation form layer to and there refered to the application of the sewage sludge and effluent and their acid effect which clear in the first, second, third group the $CaCO_3$ increase in the sub surface layer than the surface and deep layer while this sequence does not found in the forth group and the distribution referred to the parent material and the $CaCO_3$ content ranged between 8.36 and 45.98 %. Gypsum content is lowed and ranged between 0.25 and 3.97 %. EC values are low in the treated soils with the effect of sewage sludge and effluent ranged between 0.22 to 3.02 dS/m as compared with the virgin soils (11.15 to 20.19 dS/m). From the previous data it is clear the effect of sewage sludge and effluent in leaching and decrease the salts in the virgin soils. The soluble cations such as $Ca^{++} > Mn^{++} > Na^{+} > K^{+}$ varied from profile to another and from group to another and ranged such as $Na^{+} > Ca^{++} > Mn^{++} > K^{+}$ and the soluble anions take the same sequence ($Cl^{-} > SO_4^{--} > HCO_3^{-}$).

From Table (2) the cations exchange capacity (CEC) various from high in the first, and second and moderately high in third group and very low in the fourth group (in the surface layers). The values of CEC ranged between (40.52, 24.5 and 15.02 meq/100g in the treated soils and 6.02 meq/100g in the virgin soils).The variation in the CEC values could be due to the various in the period and the amount of the sewage sludge and effluent. ESP is low than 15 % which show there is no alkaline in soil. The exchangeable cations as Ca^{++}, Mg^{++}, Na^{+} and K^{+} varied from layer to another and from profile to another and from treated soils to virgin soil according to the cations exchangeable capacity which according to the texture class, the exchangeable cations ranged such as: $Ca^{++} > Mn^{++} > Na^{+} > K^{+}$.

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Fertility properties:

From Table (4) its clear that the macronutrients (NPK) high in the first, second and third groups than critical levels (25, 5 and 175 ppm for N,P and K, respectively, Walsh *et al.*, 1973). While its very low in the four the group (virgin soil) and it's varied between 187.2 to 367.6 N, 11.9 to 30.7 P, 182.3 to 352.1 K (ppm), in the first group (in the surface layer), in the second group is 187.3 to 243.2 N, 11.7 to 19.9 P, 177.5 to 284.4 K (ppm), in the third group is 87.6 to 132.8 N, 9.3 to 15.3 P, 175.8 to 207.2 K (ppm), while in the virgin soil is 13.3 to 24.0 N, 2.1 to 4.3 P, 31.3 to 102.3 K (ppm). The previous data shows the effect of using sewage sludge and effluent in improved the soil. The correlation between O.M., clay content and available (NPK) could be concluded that the following results: highly significant correlation were found between O.M and available macronutrients (r = 0.514, 0.510 and 0.418 for N, P and K, respectively), also highly significant correlation between clay content and available p (r = 0.476) and significant with N and K (r = 0.307 and r = 0.306), The virgin soil which represented by profiles 20, 23 and 24 which has not addition of sewage sludge and sewage effluent there is no correlation between NPK and OM, clay content which show effect the addition of sewage sludge and sewage effluent to improve the fertility soil properties.

Heavy metal content:-

From Table (4) the total heavy metals content in the virgin soils ranged between 4842 to 12372 Fe, 217 to 762 Mn, 27 to 73 Zn, 13 to 51 Cu, 1.0 to 2.6 Pb and 0.11 to 0.21 Cd (ppm) and the available ranged between 18 to 97 Fe, 14.7 to 54.3 Mn, 2.7 to 4.9 Zn, 2.7 to 11.6 Cu, 0.12 to 0.98 Pb and 0.02 to 0.09 Cd (ppm). While in the treated soils by using sewage sludge and sewage effluent, the total of heavy metals content varied from first, second and third group ranged between 8331 to 29642 Fe, 627 to 1960 Mn, 48 to 331 Zn, 41 to 182 Cu, 40 to 236 Pb and 0.2 to 5.1 Cd (ppm) in the first group, 81007 to 20864 Fe, 869 to 1782 Mn, 59 to 168 Zn, 38 to 140 Cu, 70 to 176 Pb and 0.5 to 4.9 Cd (ppm) in the second group and 8091 to 15672 Fe, 526 to 1301 Mn, 31 to 87 Zn, 36 to 116 Cu, 47 to 166 Pb and 0.5 to 3.9 Cd (ppm) in the third group. The bio-available heavy metals ranged between 141 to 511 Fe, 39.1 to 149.2 Mn, 4.8 to 20.6 Zn, 6.0 to 27.1 Cu, 3.2 to 22.3 Pb and 0.06 to 0.53 Cd (ppm) in the first group, 179 to 496 Fe, 35.2 to 139.5 Mn, 4.9 to 19.7 Zn, 6.8 to 16.6 Cu, 3.1 to 19.4 Pb and 0.07 to 0.47 Cd (ppm) in the second group and 112 to 402 Fe, 24.3 to 127.6 Mn, 3.6 to 18.3 Zn, 4.5 to 15.2 Cu, 1.4 to 19.3 Pb and 0.03 to 0.44 Cd (ppm) in the third group. The heavy metals content as the total and available high in the surface and subsurface layers and low in the deep layers which could refered to the effect of sewage sludge and effluent on the surface and sub surface layers and there is no effect on the deep layers which has the low content of heavy metals.

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From the previous data its clear that the effect of using sewage sludge which contains about of heavy metals as the following 13600 Fe, 1560 Zn, 436 Mn, 370 Cu, 250 Pb and 5 Cd (ppm) and the sewage effluent also contains about of heavy metals as the following 2 Fe, 0.9 Zn, 0.4 Cu, 0.3 Mn, 0.2 Pb, 0.02 Cd (ppm), and the effect does not refered to the content of heavy metals only but also refered to the period of application which ranged between 20, 15, 5 and zero years and the amount of sewage sludge addition which ranged between 5-7 ton/feddan/year and amount of sewage effluent which using in irrigation ranged between 5000 and 7000 m^3/feddan. From the previous it could be that the effect of sewage sludge and sewage effluent addition to improve the soil properties must to be according to the scientific program to protect the soil from changed to polluted soil.

CONCLUSION

From the previous data its clear that the effect of using sewage sludge and sewage effluent application in the studied soil was clear through the effect on the morphological features of the profiles which developed more than that profiles which did not get applied sewage sludge and sewage effluent this was clear from colour, texture, structure, consistence, $CaCO_3$, new formation. The physical soil properties as texture, Bd, Aw, Sp were more developed under applied the sewage sludge and sewage effluent compared with the virgin soils. The chemical properties as OM%, $CaCO_3$%, EC and CEC have developed in the soil under applied sewage sludge and sewage effluent more than the virgin soil.

The fertility as macronutrients (NPK) could be high and sufficient to the plant requirement under the applied sewage sludge and sewage effluent condition compared with the virgin soil. On the other hand, increasing the content of heavy metals as a total and available in the surface of applied profiles to reach the toxicity level which effected on the roots and leaves of the plant compared with the low level of heavy metals and does not reach the toxicity level in the virgin soil. The bad effect of sewage sludge and effluent affected by the period of addition, the percent of the increase of heavy metals in the soils, and the kind of crops which cultivated in the applied soils.

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تأثير إستخدام الحمأة ومياه الصرف الصحي علي بعض خواص الأراضي الجيرية

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تقع المنطقة محل الدراسة بقرية غمازة الكبري جنوب مدينة حلوان وقد بدأ استخدامها للزراعة منذ عام 1985 بإستخدام الحمأة ومياه المجاري لتحسين خواصها. ولإجراء هذه الدراسة تم عمل 25 قطاعا ارضيا تمثل اربعة ازمنة من المعاملات بالحمأة ومياه الصرف الصحي كالتالي:20 سنة – 15 سنة- 5 سنوات – بدون معاملة (بكر) . وقد اوضحت الدراسة ان الملامح المورفولوجية متغيرة من المجموعة الاولي الي الرابعة ويتضح ذلك من تطور الملامح المورفولوجية المتمثلة في اللون والقوام والبناء والتماسك والمسامية والجذور والحدود الفاصلة. وبينت الدراسة اتجاه زيادة التطور من المجموعة الرابعة الي الأولي اما الخواص الطبيعية (القوام – الكثافة الظاهرية – الكثافة الحقيقية – الماء الميسر – السعة التشبعية) فهي متغيرة بين المجموعات الاربعة ويرجع التغير في الخواص الطبيعية لتأثير المعاملة بالحمأة ومياه الصرف الصحي .وكذلك ايضا حدث تغير في بعض الصفات الكيميائية نتيجة المعاملة السالقة الذكر (pH- المادة العضوية – كربونات الكالسيوم – الأملاح الذائبة – السعة التبادلية الكاتيونية – محتوي الجبس) .

وبالنظر الي تركيز النيتروجين والفوسفور والبوتاسيوم في الاراضي المعاملة بالمخلفات الصلبة والسائلة فإنه يتعدي الحد الحرج اما في الاراضي البكر، فكان اقل من الحد الحرج مما يعني ان المعاملة السابقة قد ادت الي زيادة تركيز تلك العناصر، وقد تبين ان هذه الزيادة كانت تدريجية مع زيادة فترة المعاملة .

كما زادت كلا من الكمية الكلية و الكمية الصالحة لامتصاص النبات من الفلزات الثقيلة تدريجيا مع زيادة فترة المعاملة بالحمأة و مياه الصرف الصحى مقارنة بالأراضى الغير معاملة. يتضح من ذلك أن استخدام الحمأة و مياه الصرف الصحى له تأثيران الأول ايجابى فى تحسن الخواص الطبيعية و الكيميائية و خصوبة التربة، بينما تأثيرها السيئ يتمثل فى زيادة محتوى الأرض من الفلزات الثقيلة.

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Table (1): Morphological description of the studied soil profiles.

Applied period year	Prof. No.	Depth cm		Symbol	Colour		Text-ural class	Struc-ture	Consistence			Efferv. with HCl	Roots	Boun-dary	New formation
					dry	moist			wet	moist	dry				
20	1	0-25	Egyptian clover	Ap.	10YR 5/2	10YR 4/2	CL	smsb	S.P.	fi.	h.	v.h.	mfm.	dS.	The surface cover by residual of fresh parts of plants and farm manure
		25-70	(Alfalfa)	C	10YR 7/3	10YR 6/4	SL	mssmsb	MS.SP.	fr.	mh.	s.	ff.	dS.	Small common hard nodules of $CaCO_3$ and gypsum and very few organic compounds
		70-120		C	10YR 7/4	10YR 6/6	LS	ssssb.	MS.SP.	mfr.	mh.	v.h.	N.	….	
	2	0-30	Fallow prepared	Ap.	10YR 5/2	10YR 4/2	CL	smsb.	S.P.	fi.	h.	v.h.	mfm.	dS.	The surface cover by residual of fresh parts of plants and farm manure
		30-75	for Alfalfa	C	10YR 6/4	10YR 5/3	SL	mssmsb	MS.SP.	fr.	mh.	v.h.	ffm.	dS.	Small common hard nodules and concration of $CaCO_3$ and gypsum and very few organo compounds
		75-125		C	10YR 6/3	10YR 5/4	LS	ssssb.	MS.SP.	mfr.	mh.	v.h.	N.	….	
	3	0-20	Barren and Natural	Ap.	10YR 5/3	10YR 4/3	SCL	ssmsb.	S.P.	fi.	h.	v.h.	mfm.	CS.	The surface cover by natural vegetation, sewage sludge hard, and fresh parts of plants
		20-60	vegetation growth	C	10YR 6/4	10YR 4/3	SL	mssmsb	MS.SP.	fr.	mh.	v.h.	ffm.	CS.	Very few parts of plants, organo manure and sewage sludge adding.
		60-120		C	10YR 6/3	10YR 5/3	LS	ssssb.	MS.SP.	mfr.	sh.	v.h.	N.	….	
	5	0-25	Alfalfa and	Ap.	10YR 6/4	10YR 4/4	SCL	ssmsb.	S.P.	fi.	h.	h.	mfm.	dS.	The surface cover by thin layer of sewage sludge and effluent fresh and few fresh parts of plants
		25-75	Sugar Corn	C	10YR 6/6	10YR 4/4	SL	mssmsb	MS.SP.	fr.	mh.	mh.	ffm.	dS.	Very low of sewage sludge and effluent and organo manure make blockclor.
		75-125		C	10YR 6/3	10YR 4/3	LS	ssssb.	MS.SP.	mfr.	sh.	mh.	N.	….	
	8	0-25	Barren and	Ap.	10YR 6/2	10YR 4/2	CL	smsb	S.P.	fi.	h.	h.	mfm.	CS.	The surface cover by fresh of residual of plants, sewage sludge and effluents and few patches of salts
		25-110	Natural vegetation	C	10YR 6/4	10YR 5/6	SL	mssmsb	MS.SP.	fr.	mh.	mh.	cfm.	….	Very few organo compound of humified, sewage sludge and effluent.
	10	0-25	Fallow after wheat	Ap.	10YR 5/4	10YR 4/3	C	vsmlsb.	VS.VP.	vfi.	vh.	h.	mfm.	CS.	Moderately cemented by clay, rich by residual of plants and sewage sludge and effluents
		25+	Extremely hard pand of clay, $CaCO_3$, gypsum and iron oxides.												Extremely cemented clay and very deep.
	11	0-25	Olive	Ap.	10YR 5/3	10YR 3/3	CL	smlsb.	S.P.	fi.	h.	v.h.	mfm.	CS.	The surface has very thin layer of fais residual plants, sewage sludge and effluents
		25 - 75		C	10YR 6/3	10YR 4/4	CL	sslsb.	S.P.	fi.	h.	h.	cfm.	CS.	Few organo compounds leached from surface of humified residual plants sewage sludge and effluents.
		75-125		C	10YR 5/3	10YR 4/3	L	mssmsb	S.P.	mfi.	h.	v.h.	N.	….	
	12	0-30	Fallow	Ap.	10YR 5/2	10YR 4/2	CL	smlsb.	VS.P.	fi.	h.	h.	mfm.	CS.	The surface cover by fresh residual plant, sewage sludge and effluents
		30-80	after wheat	C	10YR 6/4	10YR 4/3	SL	mssmsb	MS.SP.	fr.	mh.	v.h.	ffm.	CS.	very few humified organo compound and few hard nodules and soft concration of CaCo3 and gypsum.
		80-130		C	10YR 6/6	10YR 5/6	LS	ssssb.	MS.SP.	mfr.	sh.	v.h.	N.	….	

Table (1): Cont.

Applied period year	Prof. No.	Depth cm	Land use	Symbol	Colour		Text-ural class	Struc-ture	Consistence			Efferv. with HCl	Roots	Boun-dary	New formation
					dry	moist			wet	moist	dry				
20	13	0-30	Fallow	Ap.	10YR 5/4	10YR 4/4	SCL	mssmsb	S.P.	mfi.	h.	v.h.	cfm.	dS.	Many fresh residual plants, sewage sludge and effluents
		30-120	after wheat	C	10YR 5/6	10YR 4/4	L	msmsb.	S.P.	mfi.	h.	v.h.	ffm.	….	Very few humified organo compounds and few hard nodules of $CaCo_3$ and gypsum
	14	0-30	Olive	AP.	10YR 6/2	10YR 4/2	CL	Smlp.	VS.P	fir.	h.	vh.	mfm.	CS.	Common fresh residual plants, cover by sewage sludge and effluent
		30-80		C.	10YR 6/4	10YR 5/4	SL	mssmsb.	MS.SP.	fr.	mh.	S.	cfm.	CS.	Very few humified organo compound and common hard nodules of $CaCO_3$ and gypsum
		80-130		C.	10YR 7/4	10YR 5/6	LS	ssssb.	SS.NP	mfr.	sh.	S.	ffm.	….	
	17	0-30	sugar corn	AP.	10YR 6/4	10YR 4/4	CL	smlsb.	VS.P	fi.	h.	vh.	mfm.	CS.	The surface cover by fresh residual plants, sewage sludge and effluent
		30-80		C.	10YR 5/4	10YR 4/4	L	msmsb.	S.P.	mfi.	h.	h.	ffm.	dS.	Very few organo compound and common hard nodules and soft concration of $CaCO_3$ and gypsum
		80-130	Fallow	C.	10YR 6/4	10YR 4/3	SL	mssmsb.	MS.SP.	fr.	mh.	vh.	N.	….	
	18	0-25	after wheat	AP.	10YR 6/4	10YR 4/4	CL	smlsb.	VS.P	fi.	h.	vh.	cfm.	CS.	The surface cover by fresh residual plants, sewage sludge and effluent
		25-75		C.	10YR 7/4	10YR 5/6	SL	mssmsb.	MS.SP.	fr.	mh.	vh.	ffm.	CS.	Very few organo compound and common hard nodules and soft concration of $CaCO_3$ and gypsum
		75-125		C.	10YR 6/4	10YR 5/8	LS	ssssb.	SS.NP	mfr.	sh.	h.	N.	….	Few hard nodules of $CaCO_3$ and gypsum
	21	0-25	Sugar corn	AP.	10YR 5/6	10YR 4/4	CL	Smsb.	VS.P	fi.	h.	h.	cfm.	dS.	Few fresh residual plants and rich by sewage sludge and effluent.
		25-75		C.	5YR 6/6	5YR 4/6	L	mssmb.	S.P.	mfi.	h.	vh.	ff.	CS.	Very few organo co+S3mpounds, low of sewage sludge and effluents common of hard nodules and soft concration of $CaCO_3$ gypsum
		75-125		C.	5YR 6/6	5YR 4/8	SL	mssmsb.	MS.SP.	fr.	mh.	vh.	N.	…	
	22	0-30	(Alfalfa)	AP.	10YR 6/3	10YR 5/4	CL	sslsb.	VS.P	fi.	h.	vh.	mfm.	dS.	The surface cover by fresh residual plants, sewage sludge and effluent.
		30-80		C.	10YR 6/4	10YR 5/6	L	smsb.	S.P.	mfi.	h.	vh.	ffm.	CS.	Few organo compound, low of sewage sludge and effluents and common of hard nodules and soft concration of $CaCO_3$ and gypsum
		80-130		C.	10YR 7/4	10YR 6/8	SL	mssmsb.	MS.SP.	fr.	mh.	vh.	N.	….	Few hard nodules of $CaCO_3$ and gypsum
15	7	0-20	Sugar Corn	Ap.	10YR 5/2	10YR 4/2	L	msslp.	S.P.	fr.	mfi.	mh.	mfm.	dS.	The surface cover by fresh of residual of plants, sewage sludge and effluents
		20-110		C	10YR 6/6	10YR 4/4	S	s.	NS.NP.	L.	L.	mh.	ff.	….	
	9	0-30	Fallow after	Ap.	10YR 5/2	10YR 4/2	L	msslp.	S.P.	mfi.	h.	mh.	mfm.	CS.	the surface cover by fresh residual of natural vegetation and sewage sludge effluents
		30-120	Sugar corn	C	10YR 6/4	10YR 4/4	SL	mssmsb	MS.SP.	fr.	mh.	mh.	ff.	….	few of humified organo compound.

Table (1): Cont.

Applied period year	Prof. No.	Depth cm	Land use	Horizon Symbol	Colour		Textural class	Structure	Consistence			Efferv. with HCl	Roots	Boundary	New formation
					dry	moist			wet	moist	dry				
15	15	0-25	(Alfalfa)	AP.	10YR 5/2	10YR 4/2	L	mssmg.	S.P.	mfi.	h.	S.	mfm.	CS.	many fresh residual plants, cover by sewage sludge and effluent
		25-75		C.	10YR 6/4	10YR 5/4	SL	mssmsb.	MS.SP.	fr.	mh.	S.	cfm.	CS.	few organo compound many hard nodules and soft conceration of $CaCO_3$ and gypsum
		75-125		C.	10YR 7/4	10YR 5/6	LS	ssssb.	SS.NP	mfr.	sh.	S.	N.	….	common hard nodules of $CaCO_3$ and gypsum.
	16	0-30	after wheat	AP.	10YR 6/3	10YR 4/3	L	msmsb.	S.P.	mfi.	h.	S.	mfm.	CS.	the surface cover by thin layer of fresh residual plant, sewage sludge and effluent
		30-120		C.	10YR 6/4	10YR 5/4	SL	mssmsb.	MS.SP.	fr.	mh.	S.	vff	….	very few organo compound and common hard nodules and soft conceration of $CaCO_3$ and gypsum
	19	0-30	(Alfalfa)	AP.	10YR 6/4	10YR 5/4	L	mssmg.	S.P.	mfi.	h.	vh.	mfm.	CS.	few fresh residual plants and rich by sewage sludge and effluent.
		30-80		C.	10YR 7/4	10YR 5/6	SL	mssmsb.	MS.SP.	fr.	mh.	vh.	cfm.	dS.	Very few organo compounds and common hard nodules and soft conceration of $CaCO_3$
		80-130		C.	10YR 7/6	10YR 5/8	LS	ssssb.	SS.NP	mfr.	sh.	h.	N.	….	Few hard nodules of $CaCO_3$ and gypsum
5	4	0-30	Barren	Ap.	10YR 6/6	10YR 5/4	LS	ssssb.	MS.SP.	mfr.	sh.	mh.	mfm.	dS.	the surface cover by natural vegetation, sewage sludge hard, and fresh parts of plants
		30-70		C	10YR 7/6	10YR 5/6	S	s.	NS.NP.	loose.	loose.	mh.	ffm.	CS.	very few parts of plants, sewage sludge and humified organo manure.
		70-120		C	10YR 7/8	10YR 5/8	S	s.	NS.NP.	loose.	loose.	h.	N.	….	
	6	0-30	Sugar Corn	Ap.	10YR 6/4	10YR 4/4	SL	mssmsb	MS.SP.	fr.	mh.	s.	mfm.	dS.	the surface cover by fresh of residual of plants, sewage sludge and effluents
		30-120		C	10YR 6/3	10YR 4/3	LS	ssssb.	MS.SP.	mfr.	sh.	mh.	ff.	….	common partly humified residual organo compound of residual plants, sewage sludge.
	25	0-30	sugar corn	AP.	10YR 7/4	10YR 6/6	LS	S.	N.N.	L.	L.	mh.	mfm.	CS.	few fresh residual plants
		30-70		C.	10YR 6/4	10YR 5/4	S	S.	N.N.	L.	L.	h.	ffm.	dS.	few hard nodules and soft conceration of CaCO3 and gypsum
		70-120		C.	10YR 6/6	10YR 5/6	S	S.	N.N.	L.	L.	h.	N.	….	
Virgin	20	0-30	Barren	AP.	10YR 7/3	10YR 5/6	S	S.	N.N.	L.	L.	vh.	cfm.	dS.	few fresh residual plants
		30-120		C.	10YR 7/4	10YR 5/6	S	S.	N.N.	L.	L.	vh.	vff	….	few hard nodules of CaCO3 and gypsum
	23	0-30	Olive	AP.	10YR 8/4	10YR 6/8	S	S.	N.N.	L.	L.	mh.	ffm.	CS.	very few fresh residual plants
		30-120		C.	10YR 7/4	10YR 5/6	S	S.	N.N.	L.	L.	h.	rff.	….	few hard nodules and soft conceration of $CaCO_3$ and gypsum
	24	0-25	Barren	AP.	10YR 7/4	10YR 5/6	LS	ssssb.	SS.NP	mfr.	sh.	vh.	N.	CS.	very few fresh residual plants
		25-60		C.	10YR 6/6	10YR 5/6	S	S.	N.N.	L.	L.	h.	N.	CS.	few hard nodules and soft conceration of $CaCO_3$ and gypsum
		60-100		C.	10YR 6/4	10YR 5/6	S	S.	N.N.	L.	L.	h.	N.	CS.	
		100-130		C.	10YR 8/4	10YR 6/6	S	S.	N.N.	L.	L.	h.	N.	….	

Textural class abbreviations

CL:	Clay loam	S:	Sand
SCL:	Sandy clay loam	C:	Clay
SL:	Sandy loam	L:	Loam
LS:	Loamy sand		

Roots abbreviations

mfm:	many fine medium roots	Vff:	very few fine roots
ff:	few fine roots	Cff:	common fine to medium roots
ffm:	few fine to medium roots	N:	none roots
Cfm:	common fine to medium roots		

Consistence abbreviations

Wet		Moist		Dry	
SP:	Sticky and Plastic	L:	Loose;	h:	hard
vsP:	very sticky and plastic	fr:	friable	mh:	moderately hard
mssp:	moderately sticky and slightly plastic	mfr:	moderately friable	sh:	slightly hard
SSNP:	slightly plastic and non plastic	fi:	firm	L:	Loose
NN:	None sticky and non plastic	mfi:	moderately firm		
		vfi:	very firm,		

Boundary abbreviations

d:	Diffuse boundary
cs:	clear smooth boundary

Effervescence with HCl

Vst:	very strong effervescence with HCl	h:	high effervescence with HCl
St:	strong effervescence with HCl	m:	moderately effervescence with HCl
Vh:	very high effervescence with HCl	S:	slightly effervescence with HCl

Structure abbreviations

Smsb:	Strong medium subangular blocky,	vsmlsb:	Very strong medium to large subangular blocky,
mssmsb:	Moderate strong small medium subangular blocky,	smlsb:	Strong medium to large subangular blocky,
SSSSb:	Slightly strong small subangular blocky,	sslsb:	Strong small to large subangular blocky,
SSmsb:	Slightly strong medium subangular blocky,	msmsb:	Moderately strong medium subangular blocky,
Sg:	Single grains,	smlp:	Strong medium to large platy,
msslp:	Moderately strong small to large platy,	mssmg:	Moderately strong small to medium granular.

Table (2): Texture class, CEC, Exchangeable cations and ESP in the studied area.

Applied period year	Prof. No.	Depth cm	Gravels %	Particles size distribution (mm)				Textural class	CEC mg/100 g soil	Exchangeable cations mq/100 g soil				ESP %
				C. Sand %	F. sand %	Silt %	Clay %			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	
20	1	0-25	9.58	13.90	25.32	28.33	32.45	CL	26.43	13.56	10.02	2.65	0.21	10.03
		25-70	15.04	31.38	30.25	20.15	18.22	SL	16.15	8.65	6.05	1.26	0.25	7.80
		70-120	14.07	28.55	36.16	22.02	13.17	LS	10.11	5.76	3.57	0.58	0.20	5.74
	2	0-30	7.15	11.45	27.36	29.01	32.18	CL	27.21	14.56	10.04	2.38	0.23	8.75
		30-75	10.19	31.42	26.35	25.12	17.11	SL	13.75	6.42	5.91	1.22	0.20	8.87
		75-125	8.78	30.27	37.37	20.13	12.23	LS	10.02	5.27	3.84	0.72	0.19	7.19
	3	0-20	2.33	18.46	27.41	26.02	28.11	SCL	23.15	11.78	9.75	1.38	0.24	5.96
		20-60	16.06	27.13	30.51	24.22	18.14	SL	14.46	7.41	5.95	0.90	0.20	6.22
		60-120	15.25	27.35	35.12	26.12	11.41	LS	9.05	4.91	3.62	0.37	0.15	4.09
	5	0-25	6.69	15.76	26.01	28.11	30.12	SCL	23.32	12.01	9.80	1.29	0.22	5.53
		25-75	3.54	28.13	29.56	23.10	19.21	SL	14.67	7.78	5.86	0.83	0.20	5.65
		75-125	6.28	28.47	32.17	26.21	13.15	LS	10.23	5.86	3.51	0.70	0.16	6.84
	8	0-25	8.44	11.21	22.45	30.22	36.12	CL	30.22	15.64	12.02	2.30	0.26	7.61
		25-110	5.05	15.47	33.24	32.15	19.14	SL	15.14	8.08	5.82	1.05	0.19	6.94
	10	0-25	7.13	9.34	15.11	30.22	45.33	C	40.52	24.25	12.75	3.16	0.36	7.80
		25+												
	11	0-25	8.78	10.45	24.22	30.17	35.16	CL	30.16	16.03	12.15	1.62	0.25	5.37
		25 - 75	9.83	7.09	26.35	29.32	37.24	CL	32.05	17.05	13.25	1.45	0.30	4.52
		75-125	10.04	16.97	27.46	35.32	20.25	L	16.02	8.59	5.89	1.33	0.21	8.30
	12	0-30	0.76	12.64	22.13	30.11	35.12	CL	30.66	16.75	11.56	2.05	0.30	6.69
		30-80	21.31	17.74	34.66	29.35	18.25	SL	14.02	8.02	5.48	0.37	0.15	2.63
		80-130	11.35	21.9	37.36	25.32	15.42	LS	10.56	6.45	3.50	0.51	0.1	4.83
	13	0-30	12.05	13.51	27.12	25.25	34.12	SCL	30.25	16.89	11.21	1.89	0.26	6.25
		30-120	13.28	18.75	20.98	35.14	25.13	L	21.15	12.03	8.01	0.91	0.20	4.3
	14	0-30	3.57	7.10	21.46	35.23	36.21	CL	31.52	16.56	13.23	1.43	0.30	4.54
		30-80	15.26	21.47	30.77	28.41	19.35	SL	15.42	8.21	6.00	1.06	0.15	6.87
		80-130	16.12	26.16	33.67	29.61	10.56	LS	6.75	4.52	1.56	0.57	0.10	8.44
	17	0-30	9.09	11.48	19.12	32.16	37.24	CL	32.21	17.03	12.63	2.30	0.25	7.14
		30-80	8.43	19.14	20.23	35.18	25.45	L	20.98	11.23	8.76	0.79	0.20	3.77
		80-130	15.29	14.23	30.02	37.13	18.62	SL	14.25	8.34	4.66	1.04	0.21	7.30
	18	0-25	9.78	14.49	18.87	32.10	34.54	CL	30.23	16.15	12.11	1.66	0.31	5.49
		25-75	14.23	29.13	22.35	30.18	18.34	SL	14.89	8.65	4.98	1.05	0.21	7.05
		75-125	15.87	26.39	34.67	28.4	10.54	LS	7.32	4.22	2.34	0.64	0.12	8.74
	21	0-25	9.47	15.11	18.55	31.13	35.21	CL	30.56	16.45	12.14	1.54	0.25	5.04
		25-75	12.90	17.08	20.02	36.40	27.20	L	22.03	13.15	7.85	0.83	0.20	3.77
		75-125	19.74	20.05	35.50	25.35	19.10	SL	15.37	8.02	6.12	1.03	0.20	6.70

Table (2): Cont.

Applied period year	Prof. No.	Depth cm	Gravels %	Particles size distribution (mm) C. Sand %	F. sand %	Silt %	Clay %	Textural class	CEC mg/100 g soil	Exchangeable cations mq/100 g soil Ca^{++}	Mg^{++}	Na^{+}	K^{+}	ESP %
20	22	0-30	9.13	11.44	22.67	31.24	34.65	CL	30.21	16.95	11.65	1.26	0.35	4.17
		30-80	15.53	13.18	25.81	35.25	25.76	L	21.32	12.46	8.02	0.64	0.20	4.69
		80-130	14.93	18.44	33.12	30.32	18.12	SL	14.05	8.21	4.62	1.06	0.16	7.54
15	7	0-20	4.23	12.35	21.95	38.10	27.6	L	23.52	12.56	9.81	0.92	0.23	3.91
		20-110	7.89	39.87	45.72	6.66	7.75	S	5.15	2.84	1.86	0.35	0.10	6.80
	9	0-30	9.18	14.19	23.26	35.31	27.24	L	22.02	13.11	8.02	0.64	0.25	2.91
		30-120	19.39	19.68	30.02	32.15	18.15	SL	13.56	6.98	5.82	0.56	0.19	4.2
	15	0-25	10.59	13.04	25.41	36.10	25.45	L	20.65	11.51	7.86	1.07	0.21	5.18
		25-75	17.13	23.69	27.82	30.23	18.26	SL	15.11	8.13	5.75	1.07	0.16	7.08
		75-125	16.67	23.76	35.01	25.12	16.11	LS	11.05	6.02	4.21	0.71	0.11	6.42
	16	0-30	10.60	12.45	23.12	36.31	28.12	L	24.05	14.06	8.71	1.08	0.20	7.35
		30-120	13.10	21.42	33.21	27.15	18.22	SL	14.69	7.98	5.88	0.64	0.19	4.36
	19	0-30	10.42	12.25	24.17	37.26	26.32	L	21.76	12.25	8.26	1.05	0.20	4.82
		30-80	9.71	21.12	30.46	30.17	18.25	SL	14.56	8.51	4.65	1.25	0.15	8.59
		80-130	3.12	28.67	34.71	25.11	11.51	LS	8.35	5.21	2.54	0.50	0.10	6.00
5	4	0-30	14.50	25.91	30.72	27.24	16.13	LS	13.41	7.31	4.85	1.06	0.19	7.90
		30-70	10.14	37.41	46.25	7.56	8.78	S	5.04	2.56	1.98	0.38	0.12	7.54
		70-120	6.47	35.97	50.15	7.33	6.55	S	4.12	2.01	1.83	0.18	0.11	4.37
	6	0-30	6.67	27.43	27.18	27.24	18.15	SL	15.02	7.95	5.93	0.93	0.21	6.19
		30-120	8.46	25.67	30.42	28.31	15.60	LS	12.61	6.78	4.89	0.75	0.19	6.00
	25	0-30	10.13	28.45	30.12	25.12	16.31	LS	12.25	6.21	4.82	1.03	0.19	8.41
		30-70	11.03	24.15	60.02	7.81	8.02	S	4.32	2.71	1.35	0.18	0.08	4.17
		70-120	19.99	48.52	35.25	9.00	7.23	S	4.02	2.50	1.25	0.22	0.05	5.47
Virgin	20	0-30	12.11	44.15	40.25	8.20	7.40	S	5.21	2.92	1.87	0.32	0.10	6.14
		30-120	18.50	42.17	43.11	9.10	5.62	S	3.56	1.85	1.35	0.26	0.10	7.30
	23	0-30	6.70	34.74	50.03	7.03	8.20	S	5.18	3.02	1.51	0.53	0.12	10.23
		30-120	10.92	31.26	53.02	8.12	7.60	S	3.36	3.10	1.62	0.51	0.13	9.51
	24	0-25	15.66	29.41	30.25	25.22	15.12	LS	6.02	6.21	3.76	0.90	0.15	8.17
		25-60	17.04	43.92	42.96	7.02	6.10	S	3.51	2.12	1.13	0.15	0.11	4.27
		60-100	8.69	39.48	46.63	8.22	5.67	S	3.20	2.02	1.00	0.12	0.06	3.75
		100-130	1.89	40.00	48.22	5.91	5.87	S	3.12	2.00	1.00	0.12	0.05	3.85

Table (3): Some Chemical properties of the studied area.

Applied	Prof.	Depth	pH	O.M	$CaCO_3$	Gypsum	EC	Soluble cations mq/100 g soil				Soluble anions mq/100 g soil			
Period (year)	No.	cm	(1:1)	%	%	%	dS/m	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO^{-}_{3}	HCO^{-}_{3}	Cl^{-}	SO_4^{--}
20	1	0-25	7.03	2.15	12.54	1.22	0.89	0.23	0.02	0.15	0.02	0.00	0.21	0.12	0.09
		25-70	7.15	1.96	25.08	2.02	0.22	0.02	0.01	0.02	0.01	0.00	0.02	0.03	0.01
		70-120	7.18	0.65	19.23	1.03	0.28	0.06	0.03	0.02	0.01	0.00	0.03	0.05	0.04
	2	0-30	7.28	2.25	20.9	0.99	1.14	0.2	0.15	0.09	0.01	0.00	0.02	0.16	0.27
		30-75	7.33	1.96	25.57	1.75	1.80	0.14	0.09	0.10	0.01	0.00	0.05	0.15	0.14
		75-125	7.33	0.63	20.74	1.67	1.22	0.05	0.04	0.07	0.01	0.00	0.02	0.10	0.14
	3	0-20	7.63	3.14	10.72	1.35	0.43	0.05	0.02	0.02	0.01	0.00	0.03	0.04	0.03
		20-60	7.48	1.12	28.54	2.12	0.72	0.11	0.04	0.23	0.03	0.00	0.26	0.11	0.04
		60-120	7.75	0.65	21.74	1.75	0.37	0.04	0.01	0.02	0.01	0.00	0.03	0.05	0.04
	5	0-25	7.53	3.35	10.03	0.76	1.14	0.20	0.15	0.09	0.01	0.00	0.02	0.66	0.41
		25-75	7.53	1.71	15.85	0.38	1.68	0.21	0.12	0.68	0.05	0.00	0.22	0.67	0.17
		75-125	7.48	0.64	15.85	0.41	1.75	0.13	0.08	0.09	0.01	0.00	0.06	0.14	0.11
	8	0-25	7.72	4.50	10.03	0.85	2.15	0.56	0.45	3.12	0.03	0.00	0.42	2.45	1.29
		25-110	7.80	2.73	15.85	0.52	1.43	0.16	0.02	0.74	0.04	0.00	0.20	0.69	0.07
	10	0-25	7.71	5.13	9.68	0.76	2.10	0.31	0.25	0.81	0.02	0.00	0.23	0.91	0.25
		25+													
	11	0-25	7.42	5.13	12.54	0.98	2.01	0.12	0.11	1.74	0.15	0.00	0.23	0.40	1.49
		25 - 75	7.53	2.34	18.36	0.78	2.02	0.13	0.12	1.72	0.14	0.00	0.24	0.30	1.50
		75-125	7.55	0.65	16.72	1.52	2.16	0.19	0.13	0.95	0.02	0.00	0.33	0.63	0.33
	12	0-30	7.60	5.13	11.70	0.89	1.50	0.09	0.04	0.19	0.02	0.00	0.07	0.17	0.10
		30-80	7.79	1.79	18.39	1.95	0.46	0.07	0.04	0.02	0.01	0.00	0.03	0.04	0.07
		80-130	7.88	0.65	12.59	1.02	0.32	0.05	0.01	0.02	0.01	0.00	0.02	0.04	0.03
	13	0-30	7.04	2.93	12.54	0.98	0.66	0.07	0.03	0.02	0.01	0.00	0.03	0.06	0.04
		30-120	7.04	1.79	14.21	0.55	2.42	0.13	0.12	1.70	0.14	0.00	0.24	0.41	1.44
	14	0-30	7.72	2.00	18.39	1.01	3.02	0.22	0.19	0.50	0.02	0.00	0.23	0.50	0.20
		30-80	8.24	0.88	25.08	2.22	2.23	0.18	0.14	0.99	0.01	0.00	0.31	0.66	0.35
		80-130	8.06	0.65	41.80	3.65	1.52	0.09	0.05	0.18	0.02	0.00	0.08	0.18	0.08
	17	0-30	7.91	5.26	12.54	1.09	2.15	1.21	0.66	13.2	0.04	0.00	0.24	10.12	4.75
		30-80	8.07	0.8	18.36	0.85	2.10	0.52	0.41	1.10	0.02	0.00	0.24	1.61	0.20
		80-130	8.06	0.65	14.21	0.99	2.10	0.50	0.43	1.12	0.03	0.00	0.25	1.58	0.25
	18	0-25	7.64	3.57	19.23	1.56	1.60	0.21	0.12	0.65	0.02	0.00	0.23	0.65	0.12
		25-75	7.74	1.45	25.90	1.79	1.32	0.07	0.10	0.23	0.02	0.00	0.15	0.23	0.04
		75-125	7.70	0.88	12.54	1.02	2.00	0.15	0.11	0.70	0.02	0.00	0.30	0.60	0.08
	21	0-25	7.92	2.11	8.36	0.98	3.01	0.53	0.42	3.02	0.03	0.00	0.35	2.21	1.44
		25-75	7.81	1.11	12.54	1.02	2.85	0.25	0.21	0.62	0.02	0.00	0.34	0.72	0.04
		75-125	7.82	0.80	14.21	1.65	2.71	0.19	0.18	0.38	0.02	0.00	0.11	0.26	0.40

Table (3): Cont.

Applied Period (year)	Prof. No.	Depth cm	pH (1:1)	O.M %	$CaCO_3$ %	Gypsum %	EC dS/m	Soluble cations mq/100 g soil				Soluble anions mq/100 g soil			
								Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO^{-}_{3}	HCO^{-}_{3}	Cl^{-}	SO_4^{--}
20	22	0-30	7.71	5.70	14.21	1.71	0.85	0.23	0.13	0.23	0.03	0.00	0.34	0.12	0.16
		30-80	7.91	1.96	20.54	1.05	0.53	0.07	0.02	0.05	0.01	0.00	0.11	0.03	0.01
		80-130	7.87	0.65	15.05	1.15	0.52	0.05	0.02	0.06	0.01	0.00	0.02	0.10	0.02
15	7	0-20	7.52	4.63	10.83	0.34	0.43	0.07	0.04	0.02	0.01	0.00	0.05	0.05	0.09
		20-110	7.56	0.65	15.85	0.52	0.22	0.02	0.02	0.01	0.01	0.00	0.02	0.03	0.01
	9	0-30	7.74	5.53	10.55	0.32	0.85	0.22	0.12	0.23	0.03	0.00	0.34	0.10	0.16
		30-120	8.03	1.36	15.85	0.25	0.32	0.04	0.01	0.02	0.01	0.00	0.03	0.03	0.03
	15	0-25	7.62	2.93	37.62	2.89	0.54	0.06	0.02	0.05	0.01	0.00	0.05	0.07	0.02
		25-75	7.93	1.79	45.98	3.97	0.65	0.07	0.03	0.05	0.01	0.00	0.04	0.08	0.04
		75-125	7.75	1.36	41.80	3.02	1.56	0.10	0.09	0.19	0.02	0.00	0.07	0.19	0.14
	16	0-30	7.55	5.55	17.59	2.02	1.73	0.21	0.11	0.20	0.02	0.00	0.08	0.21	0.25
		30-120	7.57	0.65	35.08	2.10	2.00	2.78	0.75	18.23	0.05	0.00	0.23	16.25	5.33
	19	0-30	7.86	1.79	14.21	1.03	0.42	0.05	0.04	0.03	0.01	0.00	0.02	0.09	0.02
		30-80	7.94	1.12	16.88	2.03	0.40	0.06	0.04	0.03	0.01	0.00	0.02	0.02	0.13
		80-130	7.88	0.65	11.70	0.79	0.45	0.07	0.03	0.04	0.01	0.00	0.05	0.03	0.07
5	4	0-30	7.46	2.25	11.18	0.61	1.01	0.10	0.20	0.30	0.02	0.00	0.23	0.24	0.15
		30-70	7.53	2.15	15.85	0.57	1.07	0.12	0.30	0.33	0.05	0.00	0.53	0.26	0.01
		70-120	7.47	2.08	10.36	0.73	2.62	0.12	0.11	1.74	0.15	0.00	0.23	0.4	1.49
	6	0-30	7.51	3.35	16.75	2.12	1.33	0.07	0.10	0.23	0.02	0.00	0.15	0.23	0.04
		30-120	7.45	2.93	25.85	0.26	1.72	0.13	0.09	0.08	0.02	0.00	0.05	0.15	0.12
	25	0-30	7.80	1.45	14.18	0.32	0.25	0.06	0.03	0.02	0.01	0.00	0.02	0.02	0.08
		30-70	7.63	0.65	19.20	0.75	0.35	0.05	0.03	0.02	0.01	0.00	0.02	0.03	0.06
		70-120	7.65	0.65	19.20	0.81	0.36	0.06	0.04	0.02	0.01	0.00	0.02	0.04	0.07
Virgin	20	0-30	7.93	0.89	26.9	2.34	16.63	0.21	0.12	6.68	0.02	0.00	0.20	6.68	0.15
		30-120	7.80	0.72	20.72	2.05	20.19	0.18	0.14	10.01	0.02	0.00	0.34	10.66	0.50
	23	0-30	7.96	0.80	14.18	0.32	11.15	0.20	0.14	5.09	0.01	0.00	0.03	5.17	0.24
		30-120	7.70	0.65	10.03	0.98	11.78	0.19	0.17	5.43	0.02	0.00	0.05	5.55	0.21
	24	0-25	8.16	0.93	22.54	1.03	11.82	0.14	0.08	5.69	0.01	0.00	0.06	5.14	0.12
		25-60	7.66	0.65	19.69	0.65	13.20	0.23	0.22	6.60	0.01	0.00	0.13	6.45	0.48
		60-100	7.73	0.45	18.36	1.15	13.50	0.25	0.21	6.61	0.02	0.00	0.14	7.49	0.54
		100-130	7.76	0.15	19.69	0.95	14.01	0.53	0.35	6.04	0.02	0.00	0.23	7.09	0.62

Table (4): Total and bio-available heavy metals and available macronutrients in the studied area.

Applied Period (year)	Prof. No.	Depth cm	Fe ppm		Mn ppm		Zn ppm		Cu ppm		Pb ppm		Cd ppm		Available (ppm)		
			Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	N	P	K
20	1	0-25	23642	483	1446	137.4	157	18.1	182	24.07	212	19.8	4.1	0.34	316.4	19.8	317.7
		25-70	16291	307	1331	95.4	71	12.3	165	21.6	189	11.6	3.1	0.10	52.7	10.2	233.7
		70-120	12968	268	864	87.6	48	7.6	146	19.8	70	5.3	1.7	0.07	16.1	7.6	112.5
	2	0-30	29642	511	1702	143.7	216	13.8	110	22.6	196	19.7	4.4	0.39	270.3	12.2	216.8
		30-75	20122	388	1243	111.3	101	12.6	98	10.7	140	17.8	2.1	0.17	37.4	8.6	127.7
		75-125	15674	271	774	72.8	99	8.4	76	9.2	101	4.4	1.4	0.08	10.3	4.3	91.0
	3	0-20	21626	330	1934	89.5	191	18.3	102	13.1	126	10.3	5.1	0.37	218.4	28.8	396.4
		20-60	16329	201	1186	72.3	176	11.9	87	9.6	98	4.8	2.7	0.14	40.7	16.4	222.3
		60-120	11652	174	924	51.7	94	6.3	64	7.5	40	3.2	1.2	0.09	16.2	5.3	137.5
	5	0-25	21645	273	1392	143.2	246	11.1	73	19.1	176	19.4	4.1	0.29	187.2	11.9	182.3
		25-75	14941	192	1163	127.3	111	10.9	62	11.6	140	12.7	1.9	0.17	30.7	5.4	70.4
		75-125	10672	155	1016	89.5	103	7.3	54	8.3	85	3.8	1.1	0.09	9.8	2.9	31.1
	8	0-25	18431	351	1222	112.6	186	19.9	114	13.1	207	21.8	3.9	0.17	367.7	24.1	303.3
		25-110	10093	276	776	77.2	121	15.8	90	7.9	118	7.6	3.1	0.08	33.3	13.3	197.6
	10	0-25	8626	242	1542	149.2	91	19.8	126	14.2	199	10.2	4.1	0.24	269.5	20.0	187.2
		25+	Hard	Pan													
	11	0-25	18433	366	1611	90.4	164	19.9	142	16.1	162	16.1	1.9	0.53	304.2	30.7	276.3
		25 - 75	12102	209	1201	83.2	101	17.2	117	9.7	111	13.2	0.5	0.13	44.3	17.6	137.6
		75-125	8544	146	729	63.7	92	5.8	82	6.9	89	4.7	0.4	0.08	12.7	9.3	101.1
	12	0-30	20411	292	1226	121.1	176	15.7	142	16.1	162	16.1	3.9	0.28	304.2	30.7	276.3
		30-80	16532	222	1007	99.9	91	12.8	117	11.7	112	13.2	2.5	0.13	44.3	17.6	137.6
		80-130	11009	189	673	86.3	80	9.6	52	6.9	89	5.7	1.2	0.07	12.7	9.3	101.1
	13	0-30	20976	306	1612	53.4	107	19.1	92	10	179	10.1	1.7	0.33	197.6	15.1	217.0
		30-120	18924	141	1173	39.1	89	16.4	78	6.2	132	6.4	0.5	0.08	30.4	8.6	109.3
	14	0-30	20673	398	1582	150.3	94	11.9	112	15.2	199	13.2	1.6	0.27	352.1	23.3	312.5
		30-80	15762	272	1111	119.6	80	9.3	107	11.7	115	10.9	1.0	0.10	62.3	12.2	216.3
		80-130	8331	151	983	88.7	72	4.8	95	7.9	42	7.6	0.6	0.06	20.8	5.9	139.9
	17	0-30	17761	284	1762	55.2	152	18.7	113	9.1	212	14.4	3.9	0.39	270.3	16.4	198.4
		30-80	12883	233	1113	51.3	143	13.5	59	7.7	107	11.9	1.7	0.15	39.1	10.1	123.2
		80-130	10424	116	627	48.7	117	10.4	41	6.9	42	3.3	1.2	0.09	19.5	5.7	99.1
	18	0-25	10133	398	1226	119.7	149	20.6	143	27.1	277	15.4	3.2	0.38	196.3	12.7	212.1
		25-75	9671	272	817	103.1	68	17.6	126	15.8	236	12.3	1.8	0.11	80.8	6.8	180.4
		75-125	9003	199	698	99.9	48	11.4	91	9.7	112	4.9	0.7	0.09	17.6	2.9	97.1
	21	0-25	16431	402	1960	113.3	163	19.9	112	12.3	144	15.2	3.2	0.43	223.3	20.1	277.1
		25-75	15765	276	1697	66.2	66	16.2	79	11.8	103	9.8	3.0	0.27	99.3	12.7	176.3
		75-125	14869	250	1114	60.1	57	11.0	63	10.9	69	4.2	1.7	0.07	20.5	5.2	87.4

Table (4): Cont.

Applied Period (year)	Prof. No.	Depth cm	Fe ppm		Mn ppm		Zn ppm		Cu ppm		Pb ppm		Cd ppm		Available (ppm)		
			Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	Total	Avail.	N	P	K
20	22	0-30	23941	281	1330	73.7	331	19.2	122	17.6	199	22.3	3.1	031	346.3	29.7	352.1
		30-80	17369	263	1201	52.4	176	16.5	107	11.9	113	11.0	3.1	0.10	50.1	18.4	217.6
		80-130	15121	211	998	40.3	93	9.9	89	6.0	52	3.6	2.7	0.06	19.7	12.3	109.1
15	7	0-20	19652	416	1296	116.3	168	17.1	116	16.6	135	19.4	1.9	0.39	211.1	19.7	190.8
		20-110	8107	280	891	107.5	144	14.4	51	11.2	112	5.8	1.5	0.07	30.7	10.1	43.7
	9	0-30	19677	198	1773	139.5	191	17.6	140	13.7	181	18.2	2.8	0.25	187.3	17.6	177.5
		30-120	8095	179	1172	63.2	92	10.9	111	7.9	70	3.7	1.6	0.09	22.2	9.1	97.3
	15	0-25	20301	421	1762	113.3	88	10.1	57	8.2	146	12.3	4.9	0.47	243.2	19.9	284.4
		25-75	18962	243	1214	60.1	71	7.7	49	7.8	110	10.9	2.5	0.12	41.0	9.9	201.1
		75-125	16883	233	887	35.2	59	4.9	38	6.9	97	5.6	1.0	0.07	17.6	4.5	107.6
	16	0-30	21611	342	1782	100.7	110	19.7	126	13.2	103	15.4	3.9	0.32	199.4	11.7	200.3
		30-120	20864	320	1679	88.4	100	8.8	112	11.8	81	7.6	1.1	0.06	30.6	5.8	112.7
	19	0-30	18412	496	1627	118.4	82	15.4	112	13.6	176	11.1	2.4	0.25	217.5	17.7	179.2
		30-80	17964	362	1532	102.2	74	11.3	97	10.2	153	9.9	1.1	0.10	89.4	9.9	99.1
		80-130	12011	253	869	99.3	65	6.7	83	6.8	120	3.1	0.6	0.07	12.3	4.8	70.8
5	4	0-30	10163	207	769	33.3	87	8.3	55	6.2	81	5.9	1.7	0.11	132.8	15.3	175.8
		30-70	9531	188	719	27.6	41	6.7	42	5.1	59	3.4	1.5	0.09	40.7	13.4	101.3
		70-120	8091	112	526	24.3	37	3.1	32	4.5	47	2.7	0.7	0.05	19.2	8.1	78.6
	6	0-30	15672	402	1301	127.6	66	18.3	116	15.2	166	19.3	3.9	0.44	103.3	12.3	182.0
		30-120	9731	327	937	115.2	58	11.6	82	5.1	126	6.8	1.1	0.11	19.7	5.4	90.7
	25	0-30	12443	213	862	59.8	59	10.1	52	7.8	63	7.5	1.1	0.09	87.6	9.3	207.2
		30-70	10846	148	616	47.6	49	4.2	48	6.1	55	3.4	0.6	0.07	39.7	8.5	107.1
		70-120	8327	117	533	30.7	31	3.6	36	4.9	49	1.4	0.5	0.03	11.2	7.2	81.3
Virgin	20	0-30	10113	30	703	28.1	73	4.9	19	10.0	1.6	0.9	0.2	0.09	24.0	2.1	31.3
		30-120	9711	18	327	22.3	59	3.8	13	7.0	1.0	0.8	0.19	0.07	7.0	1.1	26.5
	23	0-30	10162	86	392	37.6	36	4.1	42	11.3	2.6	0.98	0.21	0.09	15.4	4.3	102.3
		30-120	6982	73	217	24.6	33	2.7	33	9.8	2.4	0.76	0.18	0.07	7.6	3.6	88.4
	24	0-25	12372	97	762	54.3	41	5.1	51	11.6	2.2	0.87	0.19	0.09	13.3	4.2	86.7
		25-60	10689	94	633	59	39	4.7	49	10.8	2.1	0.76	0.17	0.08	10.7	3.8	80.2
		60-100	6968	82	421	37.6	31	4.2	38	8.9	1.8	0.71	0.15	0.06	8.2	3.4	78.6
		100-130	4842	79	265	14.7	27	3.1	19	2.7	1.5	0.12	0.11	0.02	6.1	2.2	19.4