J. Agric. Sci. Mansoura Univ., 27(8): 5629 - 5636, 2002

FACTORS INFLUENCING THE SOIL PENETRATION RESISTANCE OF SOME VERTISOLS IN EGYPT.

Ghabour, Th. K.; F. B. Labib and I. S. Rahim
Soils & Water Use Dept., National Research Centre, Dokki, Cairo, Egypt.

ABSTRACT

The current study aims to determine the soil penetration resistance of some Vertisols as well as to study the main contributing soil factors. Investigation of undisturbed soil samples, of eighteen profiles represent the Vertisols in Egypt, showed that the soil penetration resistance ranges between 11.3 and 45.6 N/cm^2, as affected by different soil constituents and characteristics. The monovariant analysis reveals that clay content, water stable aggregates, total carbonates and organic matter contents are positively correlated with the soil penetration resistance. Whereas, the total soluble salts is negatively and non-significantly correlated to soil penetration resistance. However, none of the simple linear regression equations could represent this relationship or predict soil resistance values for given values of the soil factors. The multivariate analysis results in very highly significant multiple linear regression equation with high correlation coefficient, meaning that the computed equation could represent the relationship between soil penetration resistance and soil constituents and characteristics under consideration. The partial correlation analysis shows that water stable aggregates, clay content and total carbonates are the most effective soil factors on the soil penetration resistance and are followed by organic matter content and total soluble salts. As a conclusion, the soil penetration resistance is not a function of one soil factor but several factors.
Keywords: soil penetration resistance, Vertisols.

INTRODUCTION

Vertisols are soils that have specific morphological features by which they could be easily recognized in the field. Other soil characteristics, which could be measured in the laboratory, are indicators to identify this type of soil. The Vertisols are, generally, the soils having, after the upper mixed 20-cm, 30 % or more clay in all horizons to depths of at least 50 cm. Such soils develop cracks from the surface downward which at some period in most years (unless the soil is irrigated) are at least 1 cm wide to a depth of 50 cm. Vertisols have one or more of the following: gilgai microrelief, intersecting slickensides, or wedge-shaped or parallelepiped structural aggregates at some depth between 25 and 100 cm from surface. These are dark coloured soils having uniform fine or very fine texture and a low content of organic matter, but perhaps their most important property is the dominance in the clay fraction of expanding lattice clay usually montmorillonite which causes these soils to swell upon wetting and shrink as well as crack upon drying, (Soil Survey Staff, 1999).

Penetrometer pressure of any soil expressed as penetration resistance is an important indicator of the mechanical stress experienced by plant roots growing in that soil, (Greacen et al, 1968; Eavis and Payne, 1969 and Whiteley *et al*, 1981). Ghazy *et al* (1986), stated that maximum vertical resistance occurred in the subsurface layers. The statistical analyses reveal that resistivity was inversely related to sand content, total porosity and moisture content. However, a strong positive relationship between resistivity and both clay and bulk density has been established. The values of path coefficients reveal that the highest direct effect on resistivity is related to bulk density, while the indirect one to total porosity and moisture content. El-Badawi (2000), stated that bulk density and infiltration rate did not show any significant relationship with compaction as a result of soil resistivity. He added that, this might be due to the unique behaviour of Verisols. Grant and Lafond (1993), concluded that penetration resistance and bulk density of a heavy clay soil increased with depth under all sequence and management systems. Misra (1989), found that the maximum penetrometer pressure increased with growing size of aggregate, aggregate confinement and decrease in the water potential to which aggregates were dried. El Araby *et al* (1986), in their study on some heavy clay soils, concluded that penetration resistance increased with soil depth. Fathi *et al* (1976), found that the pedality of the non-saline and non-alkali alluvial soils of Egypt is affected mainly by the amount of clay and partly by the management processes.

The object of the current study is to determine the soil penetration resistance of some Vertisols. It is also aiming at studying the effective soil factors contributing in penetration resistance of the investigated soils.

MATERIALS AND METHODS

A number of eighteen soil profiles, representing some Vertisols in Egypt (Fig. 1), have been selected to perform the current study. These profiles were morphologically investigated according to FAO guidelines (1990). Disturbed and undisturbed soil samples representing each layer of the examined profiles were collected for laboratory analyses. The disturbed soil samples were air dried and then sieved from 2-mm sieve. They were undergone for some routine physical and chemical analyses. Particle size distribution was conducted using the International Pipette Method according to Gee and Bauder (1986). The water stable aggregates were determined using wet sieving technique described by Kemper and Rosenau (1986). Total soluble salts were measured using the electrical conductivity meter, (Rhoades, 1982). Total carbonates were estimated as carbon dioxide gas volume using Scheiblers Calcimeter and calculated as calcium carbonates, (Nelson, 1982). Organic matter content was determined by Walkely and Black rapid titration method, (Black *et al*, 1982). While triplicate undisturbed soil specimens were sampled in metal cores (4.9 x 5.0 cm) for each layer to measure the mechanical resistance. Penetration resistance, as an expression of soil compactness was determined by compact type penetrometer, (Callebaut, 1985). The soil penetration resistance was measured under constant soil moisture potential and expressed as Newton/cm^2 (N/cm^2).

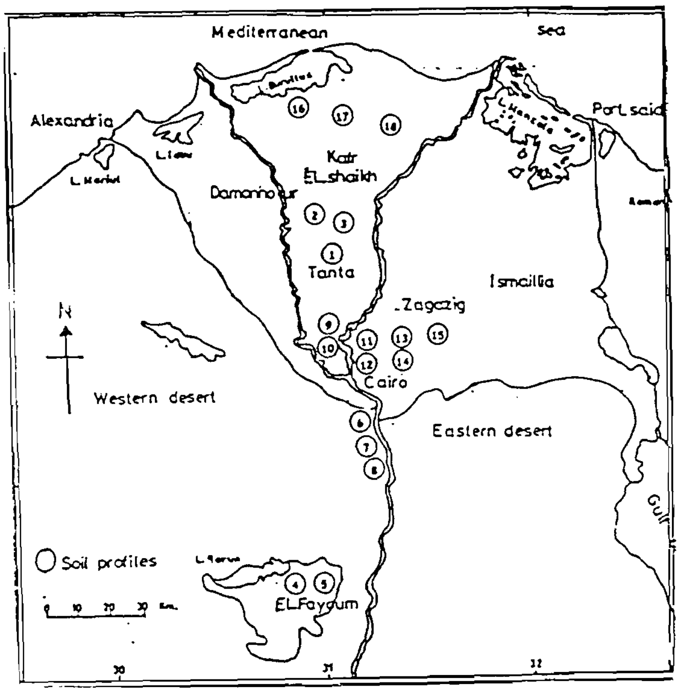

Fig. (1): Location map of the studied soil profiles.

RESULTS AND DISCUSSIONS

Soil analyses

The soil characteristics, which are selected for the current study to be investigated as factors affecting soil resistance, are clay content, water stable aggregates, total soluble salts, organic matter and calcium carbonate content. Table 1 shows the results of these measured soil characteristics and the corresponding soil penetration resistance.

The analysis of Vertisols as represented by the studied soil profiles showed that the soil penetration resistance ranges between 11.3 and 45.6 N/cm^2, as affected by different soil constituents and characteristics. The soils of the investigated profiles could be identified as heavy clayey soils, where the clay contents are amounted to 47.3 and 70.6 %. The percentages of total carbonates are fluctuating from 0.54 to 13.90 % and the organic matter content varies from 0.29 to 2.03 %. The studied soils are found to be non- to moderately saline, where electrical conductivity of their saturated soil paste extracts is ranging between 0.56 and 7.80 dS/m. Water stable aggregates of the soils under consideration are ranging between 29.4 and 47.6 %.

Statistical analysis

Monovariant approach

The results of the monovariant analysis are shown in table 2. The simple linear regression analysis reveals that clay content, water stable aggregates, total carbonates and organic matter contents are positively correlated with the soil penetration resistance. These results are in agreement with those of El Tony (1982). He found that water stable aggregates was positively correlated with the content of clay and organic matter of the alluvial soils in the Nile Delta. Although, in the current study it is found that water stable aggregates and total carbonates are the only soil characteristic and constituent which are significantly correlated with soil penetration resistance. On the other hand, it is found that the total soluble salts is negatively and non-significantly correlated to soil penetration resistance. However, none of these equations could represent this relationship or predict soil penetration resistance values for given values of the soil factors. As a rule, predicting values of one variable from values of another will result in unreliable predicted figures unless the correlation coefficient is high, where in the current case only the values of water stable aggregates can be used. The error of the predicted values may arise out of the fact that there are other sources of influence on the dependent variable.

Multivariate approach

One of the ways to reduce the predicting error in regression analysis is to identify and analyze the influence of more than one independent variable on the dependent variable. Therefore, the multivariate analysis was applied, where the multiple linear regression equation was computed. The equation reads:

Soil penetration resistance (SPR) in N/cm^2

$= -21.8433 - 1.1208*OM + 2.3192*WSA + 0.6744*Cal + 0.2886*EC - 0.7777*Cl$

Correlation coefficient (r) = 0.9181

Significant level of the regression equation is very high (***).

Significant levels of the equation's components are as follows:

OM **, WSA ***, Cal ***, EC *, Cl ***.

The equation is very highly significant and has high correlation coefficient, meaning that the computed equation could represent the relationship between soil resistance and soil constituents and characteristics under consideration. The multiple linear regression analysis, shows that water stable aggregates, total carbonates and total soluble salts, are positively correlated with the soil resistance. However, organic matter content and clay contents are negatively correlated with soil resistance. This means that soil resistance increases with the decrease of clay content, which is in contrary with the literature. The possible explanation is that the single dispersed clay particles content (as they are determined in the particle size distribution analysis conducted using the International Pipette Method) has a negative relationship with the soil resistance. On the other hand, the relationship between the organic matter content and soil resistance may be in need for more investigations. These relations may be due to the interaction between the different soil factors taken into consideration in the performed equation.

Table (1): Soil penetration resistance and related soil characteristics.

Soil Profile No.	Location	Layer No. & Depth in cm	Soil penetration resistance (SPR) in N/ cm^2	Clay (Cl) %	Water stable aggregates (WSA) %	Total carbonates as $CaCO_3$ %	Total soluble salts (EC) dS/m	Organic matter (OM) %
1	El-Menofia	1 (0-20)	22.40	66.00	41.10	3.27	0.56	1.91
		2 (20-50)	26.20	67.00	43.00	3.02	0.65	1.61
		3 (50-100)	27.70	70.00	44.30	3.26	1.69	1.33
2	El-Gharbia	1 (0-20)	27.20	59.00	40.70	3.54	0.59	1.84
		2 (20-40)	26.00	62.00	40.80	4.22	0.65	1.39
		3 (40-100)	18.30	61.00	36.90	4.50	0.69	1.08
3	El-Gharbia	1 (0-25)	11.30	51.85	35.60	3.08	0.58	1.76
		2 (25-65)	15.10	55.00	35.80	2.46	0.66	1.35
		3 (65-110)	24.00	59.50	38.70	2.64	0.95	1.02
4	El-Fayoum	1 (0-20)	23.30	47.30	33.90	7.39	1.13	1.80
		2 (20-50)	25.70	53.60	36.50	8.75	1.24	1.47
		3 (50-100)	36.40	60.40	43.50	7.62	1.06	1.03
5	El-Fayoum	1 (0-40)	29.80	52.70	38.10	8.75	1.15	1.77
		2 (40-80)	28.20	51.70	36.50	10.50	1.05	1.62
		3 (80-120)	31.50	50.20	36.50	12.50	1.00	0.90
6	El-Giza	1 (0-30)	23.40	52.00	35.60	7.17	1.19	1.85
		2 (30-60)	24.40	56.30	37.60	5.64	1.68	1.33
		3 (60-100)	24.50	56.70	38.20	3.85	1.50	1.10
7	El-Giza	1 (0-30)	31.10	51.95	38.40	5.89	3.83	1.73
		2 (30-60)	19.30	53.84	38.00	2.05	1.54	1.12
		3 (60-100)	18.00	56.63	36.70	2.15	1.66	0.90
8	El-Giza	1 (0-30)	16.60	55.40	35.30	2.16	1.30	1.97
		2 (30-60)	20.30	58.80	37.50	2.92	1.99	1.44
		3 (60-100)	29.00	59.00	41.50	1.58	1.54	0.92
9	El-Qalubia	1 (0-30)	22.00	49.50	34.90	1.60	5.00	1.02
		2 (30-60)	22.40	53.10	36.10	2.32	2.00	0.29
		3 (60-100)	13.00	52.60	31.30	2.80	6.50	0.59
10	El-Qalubia	1 (0-20)	23.80	52.00	37.30	2.20	1.08	2.03
		2 (20-70)	20.40	55.60	36.20	2.80	4.40	1.45
		3 (70-120)	22.20	53.00	36.10	1.20	4.60	0.58
11	El-Qalubia	1 (0-40)	39.00	49.70	39.80	7.60	6.90	1.70
		2 (40-70)	23.50	51.30	31.10	13.90	7.80	0.80
		3 (70-100)	21.20	52.30	35.00	13.90	5.40	0.70
12	El-Qalubia	1 (0-40)	45.60	49.70	42.70	6.40	1.10	1.91
		2 (40-70)	23.90	48.30	33.40	5.80	0.78	1.36
		3 (70-120)	17.30	49.60	29.40	4.92	0.98	0.88
13	El-Qalubia	1 (0-20)	28.10	55.67	39.60	3.62	3.00	1.92
		2 (20-70)	34.00	55.60	40.70	4.90	0.60	1.61
		3 (70-120)	20.50	58.10	37.10	6.15	0.64	1.60
14	El-Qalubia	1 (0-40)	24.50	63.30	41.80	0.54	0.77	1.74
		2 (40-80)	33.90	70.60	47.60	0.99	0.88	0.62
		3 (80-120)	18.30	66.50	39.50	0.99	0.93	0.59
15	El-Qalubia	1 (0-20)	21.70	54.50	36.30	5.15	0.85	1.78
		2 (20-70)	20.70	51.40	34.50	6.05	0.58	1.61
		3 (70-120)	21.70	50.40	34.30	5.35	0.89	0.60
16	Kafr El-Shaikh	1 (0-20)	21.40	52.00	35.90	2.67	2.19	1.82
		2 (20-45)	24.50	52.90	36.80	4.06	2.86	1.30
		3 (45-90)	20.90	63.90	39.20	3.35	1.37	1.02
17	Kafr El-Shaikh	1 (0-40)	19.10	54.20	36.30	2.75	2.12	1.85
		2 (40-70)	21.10	62.00	38.50	2.03	3.35	1.14
		3 (70-110)	19.60	64.00	37.10	1.98	1.31	0.94
18	Kafr El-Shaikh	1 (0-40)	28.7	55.30	39.00	7.10	1.55	1.94
		2 (40-70)	21.9	56.00	36.10	7.62	1.27	1.72
		3 (70-120)	26.8	57.50	39.30	5.09	1.35	1.45

Table (2): Simple linear regression equations, correlation coefficient (r) and significant level (s).

Regression equations	r	s
R= 23.54 + 0.01*Cl	0.0091	ns
R= -18.98 + 1.14*WSA	0.6116	***
R= 21.12 + 0.63*Cal	0.3180	*
R= 24.13 – 0.016*EC	0.0044	ns
R= 20.44 + 2.71*OM	0.1998	ns

Table 3 contains the partial correlation coefficients of different soil factors, which are included in the multiple linear regression equation. The partial correlation analysis determines the contribution and effectiveness of each factor, which is included in the multiple linear regression equation. The data in table 3 reveal that the most effective soil factors upon soil resistance are water stable aggregates where the partial correlation coefficient is 0.9004, and total carbonates, where its partial correlation coefficient is 0.6051. They are followed by the total soluble salts where its partial correlation coefficient is 0.1769. While, the clay content is negatively correlated (-0.7361) and organic matter content (-0.1811). It could be stated, according to the partial correlation analysis, that water stable aggregates, clay content and total carbonates are the most effective soil factors on the soil resistance or in other words the soil compaction, and are followed by organic matter content and total soluble salts.

Table (3): Partial correlation coefficient of different soil factors.

Partial correlation coefficient				
OM	WSA	$CaCO_3$	EC	Cl
-0.1811	0.9004	0.6051	0.1769	-0.7361

As a conclusion of the obtained results, the penetration resistance of the soil is not a function of one soil factor but several factors that are interacting in this important quality. It is worthy to take into consideration the type of cropping pattern and the associated agricultural practices prevailing in any specific soil when assessment of penetration resistance, particularly in the heavy clay soils. The growth and distribution of plant roots, either shallow or deep type, are limited by the mechanical stress of the soil which can be predicted by the values of the penetration resistance.

REFERENCES

Black, C. A.; D. D. Evans; J. I. White; L. E. Ensminger and F. E. Clark 1982. Methods of Soil Analysis. Amer. Soc. Agronomy Inc. Publisher Madison, Wisconsin, USA.

Callebaut, F. (1985). Determination of soil surface strength with a needle type penetrometer. Soil and Tillage Res., 5:227-245.

Eavis, B. W. and D. Payne (1969). Soil physical conditions and root growth. In : Root Growth, Whittington, W. J. (ed.), 315-336, Butterworths, London.

El-Araby, A.; Z. El-Haddad and M. El-Ansary (1986). Subsoiling in some heavy clay soils of Egypt. Soil and Tillage Res., 9:207-216.

El-Badawi, M. M., 2000. Impact of agricultural machinery practices on the degradation of some characteristics of clayey soils. J. Agric. Sci. Mansoura Univ., 25 (6): 3721-3731.

El Tony, M. A. (1982). The effect of the physical and chemical properties of South Delta soils on their moisture characteristics. Ph. D. Thesis, Fac. of Agric., Ain Shams Univ.

FAO, (1990). Guideline for soil profile description. 3rd edition, F.A.O., Rome.

Fathi, A.; I. A. Zein El-Abedine; F. Labib and , A. A Wahdan (1976) . Clay in relation to pedality and stability of microstructure in Nile alluvial soils. Egypt. J. Soil Sci., 16 (1): 93-112.

Gee, G. N. and J. N. Bauder (1986). Particle size analysis. In Methods of Soil Analysis., Part I, Klute, A. (ed.), Agronomy Monograph No. 9.

Ghazy, A.; M. A. Wahab and Omar (1986). The dependence of penetration resistance on certain parameters of the soils of the Nile Delta. Egypt. J. Soil Sci. (Special Issue) 117-128.

Grant, C. A. and G. P. Lafond (1993). The effect of tillage systems and crop sequences on soil bulk density and penetration resistance on a clay soil in southern Saskatchewan. Canadian J. of Soil Sci., 73(2) 223-232.

Greacen, E. L.; D. A. Farrell and B. Cockroft (1968). Soil resistance to metal probes and plant roots. Transaction of the 9-th International Congress of the Soil Sci. Soc. Adelaide, pp. 769-779.

Kemper W. D. and R. C. Rosenau (1986). Aggregate stability and size distribution. In Methods of Soil Analysis, Part I, Klute, A. (ed.), Physical and mineralogical methods, 2-nd edition, Agronomy Monograph No. 9., pp. 422-425.

Misra, R. K. (1989). Penetration of soil aggregates of finite size. III. Wetting-drying and aggregate confinement effects on the penetrometer pressure, Soil and Tillage Research, 13:23-33.

Nelson, R. E. (1982). Carbonate and gypsum. In: Methods of Soil Analysis. Part 2, Page, A. I. (ed.), Agronomy Monograph No.9.

Rhoades, J. D. (1982). Soluble salts. In: Methods of Soil Analysis. Part 2, Page, A. I. (ed.), Agronomy Monograph No. 9.

Soil Survey Staff, 1999. Keys to Soil Taxonomy. Eighth edition, SMSS tech., Mono. No. 6., Blacksburg, Virginia,USA.

Whiteley, G. M.; W. H. Utomo and Dexter (1981). A comparison of penetrometer pressures and the pressures exerted by roots. Plant and Soil, 61:351-364.

العوامل المؤثرة فى مقاومة التربة للإختراق فى أراضى الفيرتيزول فى مصر

ثروت كامل غبور و فوقية لبيب بهنا و إبراهيم سعيد رحيم
قسم الأراضى و إستغلال المياه – المركز القومى للبحوث – الدقى – القاهرة – مصر

تهدف الدراسة إلى تقدير قيمة مقاومة التربة للإختراق فى بعض أراضى الفيرتيزول، كما تعنى بدراسة العوامل الرئيسية فى التربة المساهمة فى مقاومة التربة للإختراق.
و قد تم تقدير قيم مقاومة التربة للإختراق فى عينات التربة الغير مبعثرة و الممثلة لعدد ثمانية عشر قطاعا من أراضى الفيرتيزول، و أظهرت النتائج أن مقاومة التربة للإختراق فى أراضى الفيرتيزول المدروسة تراوحت بين ١١,٣ و ٤٥,٦ نيوتن/سم٢ و ذلك بتأثير المكونات و الخواص المختلفة للتربة.

و لقد أظهر التحليل الإحصائى الأحادى للنتائج المتحصل عليها أن محتوى التربة من الطين و نسبة التجمعات الأرضية الثابتة فى الماء و محتوى التربة من الكربونات الكلية و المادة العضوية لها علاقة موجبة مع مقاومة التربة للإختراق، بينما المحتوى من الأملاح الكلية الذائبة فلها علاقة سلبية. إلا أن أى من معادلات الإنحدار الخطى البسيط المتحصل عليها لم تمثل العلاقة تمثيلا دقيقا.

أما التحليل الإحصائى المتعدد العوامل فقد بين أن معادلة الإنحدار الخطى المركب ذات معنوية عالية جدا و معامل الإرتباط عالى، و هذا يعنى أن هذه المعادلة تمثل العلاقة بين مقاومة التربة للإختراق و مكونات و خواص التربة أدق تمثيل. كما بينت معاملات الإرتباط الجزئى أن التجمعات الأرضية الثابتة فى الماء و محتوى التربة من الطين و الكربونات الكلية هى أكثر خواص و مكونات التربة تأثيرا على مقاومتها للإختراق، ويليها على الترتيب محتوى التربة من المادة العضوية و الأملاح الكلية الذائبة.