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A STUDY ON SOIL STRENGTH OF CALCAREOUS SOILS AND THEIR RELATION TO CROP PRODUCTIVITY.

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ABSTRACT

The current study was conduct to evaluate the impact of soil strength of calcareous soil, expressed by penetration resistance on crop yield. Two sites representing West Nubaria namely, Tieba and Bangar El-Sokkar were selected for this study. The obtained results indicated that the soil penetration resistance, displayed highly significant positve relationships with each of CaCO3 content, bulk density and silt + clay content neverthless, it displayed a negatively highly significant relationship with soil porosity. The study also revealed significant relationships between soil penetration resistance and each of maize and wheat yield.

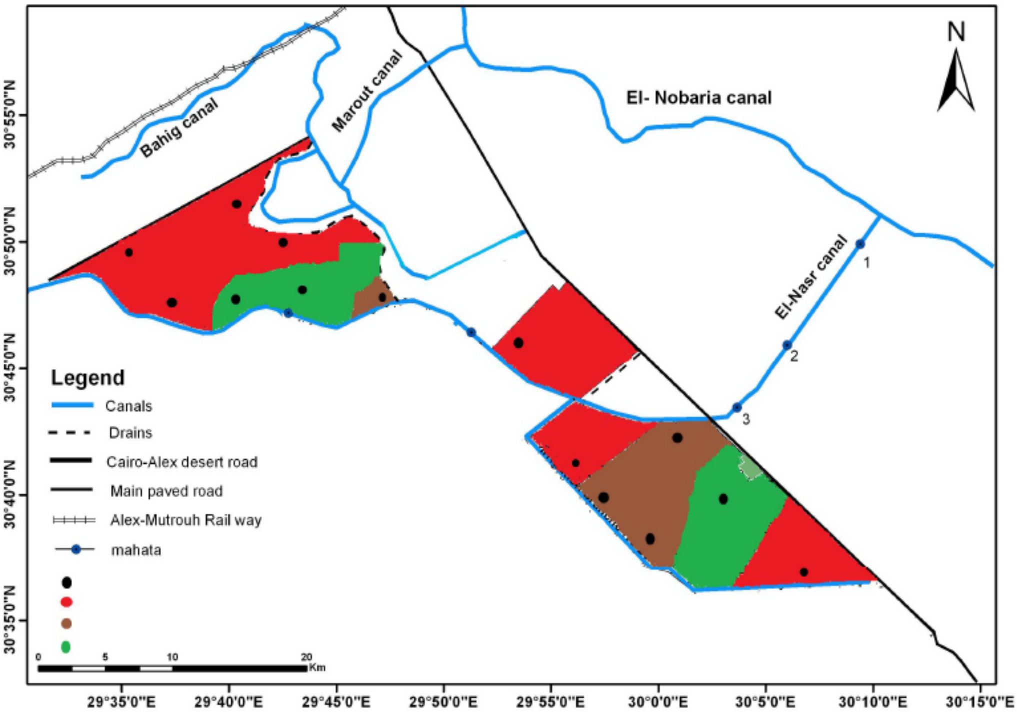
INTRODUCTION

In agriculture, soil compaction generally refers to the negative aspects of volume decrease and deformation of soil by anthropogenic causes, especially piled traffic which often is not adopted to soil type, structure and water content, Hum and Badmgart (2000).The detrimental effects of soil compaction were reported by many investigators in a number of ways; decrease plant growth, restricted root growth, reduced soil aeration and water infiltration,minimize internal drainage. Accordingly, soil compaction decreases the effectiveness of drainage system, increase the machine motorization and energy costs for tilling the soil. It also affects many other economical and environmental consequences on agriculture production.(Soane and Van Ouwerkerk (1994), Hillel, (1992) , Scott(2000) and Sumner (2000). Soil compaction increase bulk density and reduces soil porosity which can adversely affect soil aeration and soil water relationship. The ultimate result is a significant reduction in foot development and plant growth. (Horn (1988) Soil properties greatly influences the soil compactness. In brief, gravelly soil are less compressible than sandy or finer texture soils. Holloway (1990) reported that soil compaction was assessed in terms of soil strength as measured with a Pentrometer resistance and the same soil after five passes of 7.610 kg tractor. The strength of virgin soil was increased by wheel traffic and agricultural operation in all cases. Ohu and Folounzo(1989) reported that the total yield(plant+grains) of sorghum increased with increasing number of tractor wheel passes up to a certain level and then decreased with further increase in the number of passes. Compaction can be beneficial to some crops, particularly in a dry climate and with coarse- textured soil of low water holding capacity. In this respect, some values of the critical limits for specific plant growth factorsr affected by compaction. Among these, a value of 2 - 2.5 MPa is often cited as a critical penetration resistance beyond which plant root elongation is severely restricted Taylor (1971).

Due to the fact that El-Nubaria is a newly reclaimed area representing an important resource of the country, a major investiment have been already spent, neverthless the present production in many locations within such area is below its full potential. Therefore, the current study aims at evaluation of the most important factors which negatively affect the crop production in this area. It is believed that the soil strength, particularly under the calcareous nature of soil such an area, negatively influence the growth and productivity of many of the cultivated crops.

MATERIALS AND METHODS

The present work aims at investigating the most important factors affecting soil strength, and its relation to the productivity of two chosen crops, i.e. maize and wheat which represent summer and winter field crops, respectively. Two sites namely Tieba and Bangar El-Sokkar representing the northern and southern sites of El-Nasr Canal, were chosen for this study. In each site, 7 soil profiles were chosen to represent the most prevailing soil textural classes, $CaCO3$ and per feddan crop productivity, Map (1). Each profile was morphologically studied and disturbed and undisturbed samples were collected from the different layers, for laboratory analysis. Soil strength was measured very close to each of the chosen profiles using an electrical penetrometer. Because, soil strength is strongly affected by soil moisture content, soil samples were taken from each depth and very close to the penetrometer cone, in which soil moisture was measured. Determination of particle size distribution, soil bulk density, $CaCO_3$ content and penetration resistance were carried out using the standard methods described by Richard (1954)and Klute (1986). Meanwhile statistical analysis were carried out according were carried out according to Spiegel 1961.



Map (1) Location Of The Study Area And Its Infra- Structure

RESULTS AND DISCUSSION

1- Soil properties:

As the studied soil profiles widely differ in texture, thickness and sequence of their layer, the weighed average values of the obtained soil properties were calculated for 0 - 25cm and 25 - 50cm depths. Likewise, the recorded values of the penetration resistance of each soil depth (in MPa) were statistically correlated with the corresponding measured values of soil moisture content. The highly significant negative relationships were obtained and could be represented by the following regression equations:

Y = - 0.1441 X + 3.3729 **For Tieba site**

Y = - 0.2533 X + 6.3749 **For Bangar el- Sokkar site**

Where:

Y = Soil strength, Mpa.

X = Moisture content at time of measuring the penetration resistance

Apprantly, such equations reveal that, irrespective of soil constituents; soil strength appreciably decreases with increasing soil moisture content. However, the magnitude of decrease with increasing soil moisture content is not consistent in the different locations, indicating that some factors other than soil moisture influence the soil strength. To compare the strength of the studied soil profiles, the above mentioned equations were used for estimating the values of soil strength of the two layers of all profiles at constant soil moisture potential. The chosen potential corresponds 20% of the available water of the soil. The obtained calculated values are presented in Table (1). The obtained results can be summarized under the following subheading.

a- Tieba Site:

Data given in Table (1) show that the soils of Tieba vary in their texture from sand (profile No. 1, 2 and 3) to loamy sand (profiles No. 4 and 5) and sandy clay loam (profile No. 6and 7). The data also point out that the soil is uniform in texture within the top 50cm. Silt + clay content considerably faries from about 2% to 51.7%. with respect to $CaCO_3$%, the data indicates that it is ranging from less than 10% in profiles No. 5 and 7 and from 10 to 20% in profiles No. 1, 2, 4, 6 and the subsurface layer of profile 3. This indicates that such area embraces non –calcareous soil in the location represented by profiles No. 5and 7 whereas the rest of this area is of calcareous nature. Considering soil bulk density, it is clear that its volue ranged between 1.50 and 1.68 Mg/m3. These relatively higher values may be attributed to the sandy nature of Tieba soils, where total sand represents more than 50% of the soil matrix. Consequently total porosity varies within very narrow range i.e. from 37.08 to 42.60%. It is also evident that the bulk density of the subsurface soil layers was higher than the corresponding values of the surface layers, and the opposite is true for soil porosity Table (2) shows that the p^H of the soil saturated extract of Tieba site ranges between 7.6 to 8.2 indicating that such soil are slightly alkaline. However, the values of soil salinity expressed by the values of electrical conductivity of the saturated paste extract, (EC_e) prove that the soil is non-saline except being is the surface soil layer of profile No. 1 whose EC_e approached 11.5 dS/m indicating saline conditions.

As for the ionic composition of the soil solution, it is evident that sodium is the dominant cation followed by calcium and magnesium. Meanwhile, chloride and $SO4^{2-}$ are the prevailing anions.

To find out the relationship between soil strength and each of the relevant soil properties, the weighed values of the penetration resistance calculated at constant soil water potentials for depths 0 – 25, 25 – 50 cm and the corresponding weighed values of each of silt + clay content, bulk density and porosity were statistically correlated. The data indicated highly significant correlation between each variable and soil penetration resistance. Therefore, regression analysis was established and the obtained formule are given in Table 3. However, it is striking to notice, in case of the sandy soils of Tieba site, that the relationship between soil peneration resistance and silt + clay content in both surface and subsurface soil is not significant. Most probably, this behaviour could be attributed to the extremely low surface area of the soil poticles with consequent few points of contact among then and hence undetected soil resistance (Soane and Van Oawerkerk, (1994)). In contrast, in case Tieba relatively finer textured soils, i.e. profiles 4, 5, 6 and 7, soil strength displayed highly significant positive relationship with silt + clay.

These results are concomitant with those reported by Tackett and Petrson (1965) who found that increasing the silt content from 5% to

22.6 caused a sharp rise in soil strength, and addition of 5% clay to soil containing 22.6% silt doubled the soil strength. Considering the relationship between the strength of the two Tieba soil types i.e. coarse and fine – textured soils and the other studied properties, i.e. bulk density, porosity and CaCO3 content, the obtained formulas indicated significant positive linear functions between penetration resistance and each of soil bulk density and CaCO3 content, whereas the relationship between penetration resistance and soil porosity was represented by a negative linear function.

Table (1) Particle size distribution, bulk density (Db), total porosity (P) and total calcium carbonate content, penetration resistance (PR) and crop yield in Tieba site:

Profile No.	Depth cm	(PR) Mp_a	Particle size distribution %					D_b Mg/m^3	P %	$CaCo_3$ %	Crop yield	
			Coarse textured soils									
			Coarse sand	Fine sand	Total sand	Silt + clay	Texture class				Corn Ardab/fed	Wheat Ardab/fed
1	0 – 25	1.73	57.39	40.74	98.13	1.87	Snad	1.66	37.36	15.62	5	6
	25 - 50	2.18	54.26	43.24	97.50	2.50	Sand	1.68	37.08	17.0		
2	0 – 25	1.65	60.79	36.42	97.21	2.03	Snad	1.58	38.08	10.85	6	6
	25 - 50	2.12	61.0	36.83	97.83	2.17	Sand	1.66	37.32	15.81		
3	0 – 25	1.53	51.91	44.65	96.56	3.89	Snad	1.50	38.88	6.70	8	8
	25 - 50	1.89	51.13	42.92	94.05	3.98	Sand	1.62	37.84	13.57		
			Fine Textured soils									
			Sand	Silt	Clay	Silt + clay	Texture Class					
4	0 – 25	2.26	82.35	6.10	11.55	17.65	LS	1.57	38.72	10.60	8	10
	25 - 50	2.59	82.13	5.28	12.59	18.18	LS	1.62	38.58	15.07		
5	0 – 25	1.65	84.88	4.80	10.32	15.12	LS	1.54	40.68	4.31	10	14
	25 - 50	1.95	84.41	2.92	12.67	15.59	LS	1.56	42.62	7.12		
6	0 – 25	3.35	48.27	24.73	27.0	51.73	SCL	1.63	37.20	18.82	5	8
	25 - 50	3.79	47.81	23.66	28.53	52.19	SCL	1.67	36.95	19.0		
7	0 – 25	1.58	71.63	13.78	14.59	28.37	SCL	1.50	40.88	5.94	12	14
	25 - 50	1.63	74.51	10.10	15.39	25.49	SCL	1.52	42.60	8.01		

Table (2) Weighted values of soil p^H and electrical conductivity of the top two layers of Tieba soil profiles.

Profile No.	Depth cm	ECe ds/m	PH
1	0 – 20	11.50	8.00
	20 – 50	2.58	15.00
2	0 – 20	4.62	8.03
	20 – 50	2.41	8.10
3	0 – 20	2.69	7.82
	20 – 50	1.67	7.94
4	0 – 20	1.29	8.15
	20 – 50	0.78	8.22
5	0 – 20	2.11	7.58
	20 – 50	1.53	7.54
6	0 – 20	0.69	8.15
	20 – 50	2.97	8.20
7	0 – 20	0.95	7.61
	20 – 50	0.56	7.77

Table (3) The correlation coefficients and regression equations between soil penetration resistance (PR) and some physical properties of Tieba site soils.

Coarse textured soils

Soil strength Y	Soil property X	r	Regression
Surface layer	S+C	n.s.	------------------------
	B. den.	0.993*	Y = 1.25 X – 0.34
	T. pros.	- 0.996*	Y = 6.66 – 0.13 X
	$CaCo_3$	0.980*	Y = 1.39 + 0.02 X
Subsurface layer	S+C	n.s.	------------------------
	B. den.	0.991*	Y = 4.70 X – 6.14
	T. pros.	- 0.993*	Y = 16.71 – 0.39 X
	$CaCo_3$	0.989*	Y = 0.72 + 0.09 X

Fine textured soils

Soil strength Y	Soil property X	r	Regression
Surface layer	S+C	0.953*	Y = 1.14 + 0.043 X
	B. den.	0.961*	Y = 14.37 X – 20.20
	T. pros.	- 0.978*	Y = 20.29 – 0.46 X
	$CaCo_3$	0.990**	Y = 0.97 + 0.13 X
Subsurface layer	S+C	0.952*	Y = 1.33 + 0.048 X
	B. den.	0.950*	Y = 12.92 X – 18.03
	T. pros.	- 0.950*	Y = 13.97 – 0.29 X
	$CaCo_3$	0.951*	Y = 0.70 + 0.15 X

Where:

Y = Penetration resistance (MPa)
X = Soil property
S+C = Silt + Clay %
B. den. = Bulk Density (Mg/m3)
T. pros. = Total Porosity %
CaCO3 = Total Calcium Carbonate

b) Bangar EL-Sokkar site:

Data given in Table (4) show that soils of the studied area are characterized by it relatively medium to fine – texture, where the textural classes vary from clay (profiles No. 9 and 10) to sandy loam (profile No. 13). In other words, silt + clay content vary from 25.74 to 68.41%. Percentages of calcium carbonate content vary from 28.77 to 49.50% indicating that such site soils are of highly calacareous nature. Penetration resistance varies from about 2MPa to about 4MPa and tends to increase with depth. It approaches its maximum in the subsurface layers of profiles No. 11 and 12. Carbonate content except few cases, displays a slight increase with depth. The data also point out that the values of soil bulk density vary from 1.23 to 1.50 Mg. m-3, Exceptional being the case of profile No. 12 where the values of bulk density were 1.51 and 1.61 for the surface and subsurface layers, respectively total porosity ranges between 38.6 and 47.6%.by comparison, the values of bulk density of soils in Bangar El-Sokkar site were obviously lower than those in Tieba site. This could be ascribed to the finer texture of the former than to that th latter. The same table also elucidates that the maize yield ranges between 4 and 12 ardab/ feddan, however, wheat yield was between 7 and 14 ardab/ feddan. As for soil salinity, Table (4) reveals that eacept for a few cases e.g. profile No. 12, that the soil of Bangar El-Sokkar are generally non-saline. However the values of PH indicate that such soils are slightly alkaline, Table (5). It is interesting to notice that the low yields of soils represented by profile No. 12, could be correlated to the relatively high peneration resistance and salinity of such soils. In order to represent mathematically the relationship between soil strength and the properites of Bangar El-Sokkar soils, a correlation analysis was conducted between the calculated PR and the wieghed vales of the relevant property. The obtained results indicated highly significant correlation between such variables, hence regression analysis was carried out and the obtained formulas are given in Table (6). In general, the obtained equations exhibit nearly similar trends to those attained for Tieba fine – textured soils.

Table (4) Particle size distribution, bulk density (D_b), total porosity (P) and total calcium carbonate, penetration resistance (PR) and crop yield in Bangar El-Sokkar site:

Profile No.	Depth cm	(PR) Mp_a	Particle size distribution %					D_b Mg/m^3	P %	$CaCo_3$ %	Crop yeiled	
			Sand	Silt	Clay	Silt + Clay	Texture class				Corn Ardab/fed	Wheat Ardab/fed
8	0 – 25	2.29	49.41	16.54	34.05	50.59	SCL	1.39	45.31	32.04	12	12
	25 – 50	2.89	31.59	23.29	45.12	68.41	C	1.33	47.63	31.06		
9	0 – 25	2.83	38.31	17.11	44.58	61.64	C	1.49	41.57	36.48	6	8
	25 – 50	3.58	35.13	7.56	57.31	64.87	C	1.50	41.92	35.31		
10	0 – 25	2.91	32.92	22.51	44.57	67.08	C	1.38	45.67	47.57	4	7
	25 – 50	2.69	32.04	22.20	45.76	67.96	C	1.39	42.14	49.53		
11	0 – 25	2.49	49.98	28.34	21.68	50.02	L	1.35	45.12	35.31	6	10
	25 – 50	3.39	41.36	33.82	24.82	58.64	L	1.38	45.67	41.85		
12	0 – 25	2.95	43.65	25.25	31.10	56.35	CL	1.51	38.63	41.36	5	8
	25 – 50	3.92	41.13	25.20	33.67	58.87	CL	1.60	39.98	52.48		
13	0 – 25	2.05	66.40	14.31	19.29	33.60	SL	1.23	49.36	28.77	12	14
	25 – 50	3.34	74.26	8.64	17.10	25.74	SL	1.29	47.83	30.73		
14	0 – 25	2.48	46.91	25.08	28.01	53.09	SCL	1.31	44.73	32.53	8	8
	25 – 50	3.63	46.14	26.15	27.71	53.86	SCL	1.38	46.92	42.43		

Table (5) Weighted values of soils p^H and electrical conductivity of in the top two layers of Bangar El-Sokkar soils profiles.

Profile No.	Depth cm	ECe ds/m	PH
8	0 – 20	2.75	8.10
	20 – 50	2.15	8.15
9	0 – 20	2.53	8.16
	20 – 50	1.28	8.28
10	0 – 20	4.36	8.24
	20 – 50	1.46	8.22
11	0 – 20	1.37	8.18
	20 – 50	1.58	8.20
12	0 – 20	6.10	8.38
	20 – 50	4.88	8.35
13	0 – 20	4.87	8.20
	20 – 50	1.57	8.05
14	0 – 20	9.67	8.12
	20 – 50	2.94	8.20

Table (6) The correlation coefficients and regression equations between soil penetration resistance (PR) and some physical properties of Bangar El-Sokkar soils.

Soil strength Y	Soil property X	r	Regression
Surface layer	S+C	0.894*	Y = 1.05 + 0.03 X
	B. den.	0.901**	Y = 2.99 X – 1.52
	T. pros.	- 0.785*	Y = 6.05 – 0.08 X
	$CaCo_3$	0.875**	Y = 0.88 + 0.05 X
Subsurface layer	S+C	0.788*	Y = 1.63 + 0.03 X
	B. den.	0.777*	Y = 4.03 X – 2.33
	T. pros.	- 0.769*	Y = 9.26 – 0.13 X
	$CaCo_3$	0.832*	Y = 1.20 + 0.05 X
	Comp.	- 0.962**	Y = 24.68 – 4.51 X

See footnotes of Table (3)

2- Crop Yield:

It is well accepted that soil strength can affect crop yield by affecting the depth and proliferation of root system within the explored soil volume. It also affects the seedling emergence. Therefore, the present work intended for clarifying the relationship between the average yield of maize and wheat, recorded for the studied farms against the weighed values of the penetration resistance in MPa of the profiles representing such farms. Correlation analysis was carried between the relative yield, i.e. the recorded yield for each farm divided by the highest yield of the crop in the studied area, and the wieghted values of penetration resistance fro surface and subsurface layers Fig. (1 and 2).

The obtained results indicated significant negative relations between each of the relative yield of maize and wheat and the wieghted values of PR for both the two soil layers. This indicates that the crop production of maize and wheat decreases with increasing the soil strength. The derived formulae are presented in Table 7, from these equations it is clear that the adverse effect of soil strength on soil productivity was appreciably higher in the coarse textured soil compared to the relatively fine ones. Evidently, adverse effect of soil strength on crop production was more promounced in the 20 – 50 cm soil layer. Most probably, this behaviour could be explained on basis that the higher vlues of soil strength in such layer may impede the growth and proferation of plant roots and hence decline the crop yield.

Table (7) The relationship between soil penetration resistance PR and crop production in Tieba and Bangar El-Sokkar sites:

Tieba coarse texture

Regressions equations	correlations coefficient		plant
Y = 31.09 – 15.13 X	-0.997^{*}	Comp. 1	Maize
Y = 26.73 – 9.88 X	-0.991^{*}	Comp. 2	
Y= 27.50 – 12.83 X	-0.977^{*}	Comp. 1	Wheat
Y = 24.33 – 8.64 X	-0.998^{**}	Comp. 2	

Tieba fine texture

Y = 16.50 – 3.51 X	-0.962^{*}	Comp. 1	Maize
Y = 16.92 – 3.21 X	-0.966^{*}	Comp. 2	
Y= 19.23 – 3.50 X	-0.955^{**}	Comp. 1	Wheat
Y = 19.59 – 3.19 X	-0.953^{*}	Comp. 2	

Bangar El- Sokkar soils

Y = 30.11 – 8.77 X	-0.913^{**}	Comp. 1	Maize
Y = 25.18 – 5.26 X	-0.885^{*}	Comp. 2	
Y= 27.27 – 6.88 X	-0.908^{**}	Comp. 1	Wheat
Y = 24.68 – 4.51 X	-0.962^{**}	Comp. 2	

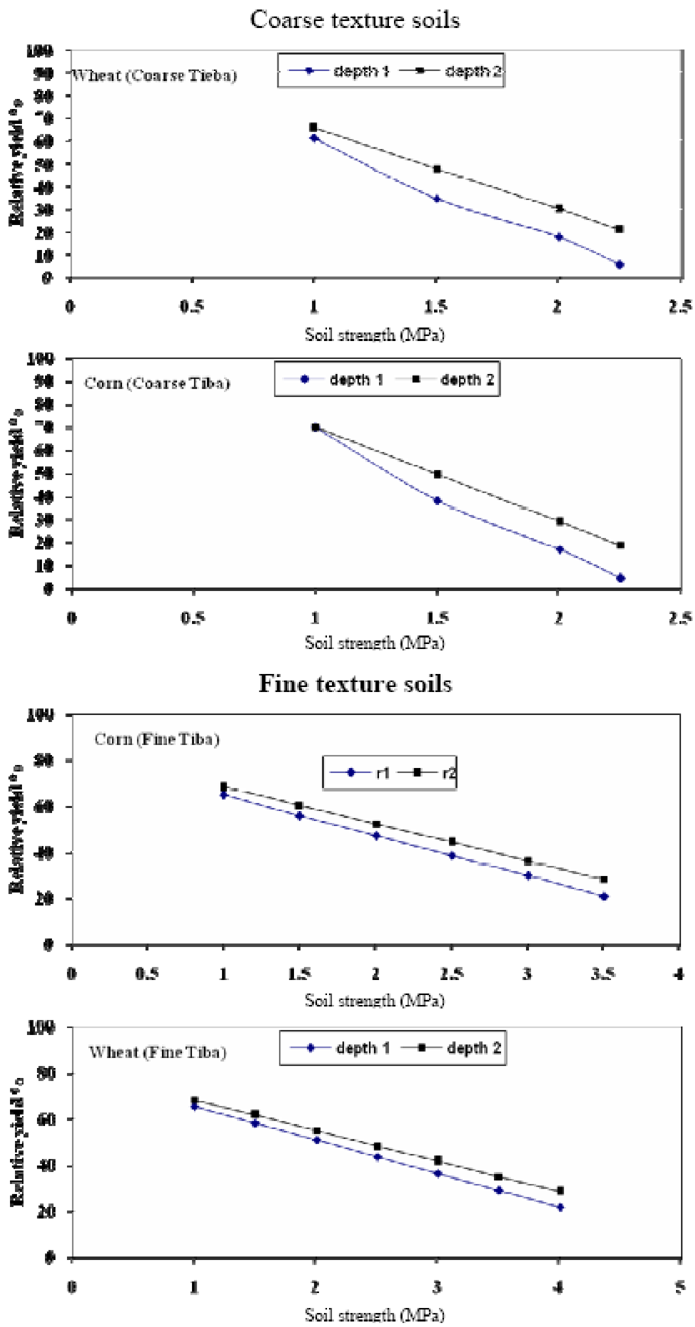


Fig. (1). The relationship between crop yield and soil penetration resistance in Tieba soils.

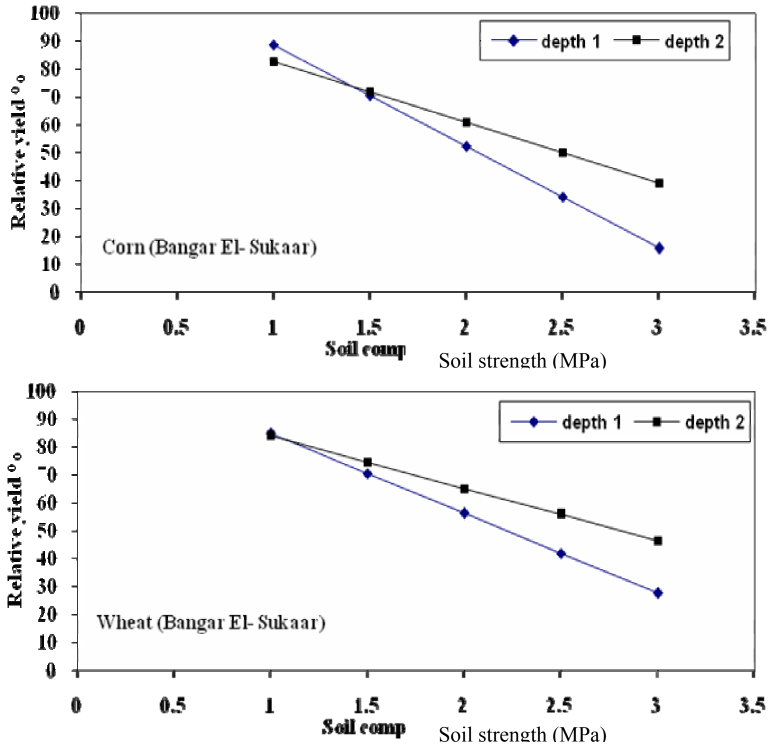


Fig. (2). The relationship between crop yield and soil penetration resistance in Bangar El-Sokkar soils

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دراسة على صلابة الأراضى الجيرية وعلاقتها بإنتاجية المحاصيل

فهمى محمد حبيب[1] – محمود يوسف عفيفى[2] – هيثم محمد شحاتة[1] ـ فرج محمد على فرج[2].

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تهدف الدراسة الحالية إلى تقييم أثر صلابة الأراضى الجيرية معبراً عنها بقيم المقاومة للاختراق على إنتاجية المحاصيل، وقد اختير لهذه الدراسة موقعان يمثلان أراضى منطقة غرب النوبارية هما منطقة طيبة ومنطقة بنجر السكر. ودلت النتائج المتحصل عليها على وجود علاقة موجبة عالية المعنوية بين المقاومة للاختراق وكل من نسبة السلت + الطين ونسبة كربونات الكالسيوم والكثافة الظاهرية. بينما دلت على وجود علاقة سالبة عالية المعنوية بين المقاومة للاختراق والمسامية الكلية. كما توصلت الدراسة إلى وجود علاقة سالبة عالية المعنوية بين المقاومة للاختراق فى كل من الطبقة السطحية وتحت السطحية وإنتاجية محصولى الذرة والقمح.