Journal

J. Biol. Chem. Environ. Sci., 2010, Vol. 5(2): 405 - 419
www.acepsag.org

COMPACTION IMPLICATIONS ON SOILS AND CROP YIELD IN EL-FAYOUM GOVERNORATE

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ABSTRACT

The current study aims at evaluating the impact of compaction on some physical properties and productivity of soils in El-Fayoum governorate.

Twenty four farms, 14 in Tamia and 10 in Fayoum, differing in their soil characteristic and management practices were chosen for this study. The obtained data of the penetration resistance(PR) for the two areas under study were relatively high and ranging from 1.06 to 3 MPa, and thus indicate relative difficulty of root – elongation through such soils. The study also indicated highly significant negative relationships between PR and both of soil organic matter and soil porosity. It also indicated a highly significant negative relation between soil productivity and the values of PR (MPa), most probably due to the limited supply of water, oxygen and nutrients, with consequent limited root growth as a result of soil compaction.

Keywords: Soil compaction, penetration resistance, roots elongation, soils of El-Fayoum Governorate.

INTRODUCTION

It is well known that the top layer of agricultural soil experiences cycles of loosening and compaction during the year. This is due to tillage, traffic and inherent soil processes triggered by soil biota. On the contrary, most of sub-soils that are below ploughing depth display a rather higher compaction state. Compaction in both the topsoil and subsoil results in negative impacts on crop production due to the reduction in root development which may affect the efficiency of the use of water and nutrient (Soane and Van Ouwerkerk, 1994). This may force farmers to use more fertilizers and irrigation water and may enhance negative environmental impacts of agriculture. Koolen and Kuipers (1983); Horn (1988) and ISTRO (1993) showed that the principle factors affecting mechanical compressibility of soil depend on both internal and external factors. The internal factors include parameters; e.g. grain size distribution, type of clay mineral, organic matter content, bulk density, pore-size distribution and soil wetness; that influence the ability of soil to withstand loading, whereas the external factors, such as kind of loading, load intensity, time and number of compaction events acting against the internal factors.

Likewise, Hassan, (1998); Hakansson and Voorhess, (1998) and Abdel-Kawy, (2005) reported that soil compaction occurs as a result of improperly timed use of heavy machinery, misuse of irrigation water and absence of conservation measurements. Schothorst (1968); El-Badawi (2000); Sadaka (1988); Kandil (1990) and Abou – Arab *et al* (1998) reported that compaction could be considered as an increase in dry bulk density due to human activity and the change in physical properties. It reduces soil porosity which can adversely affect soil aeration and soil-water relationships and thus influences plant growth.

As for the assessment of soil compaction and factors affecting it, Hassan (1998) and Ahmed (2003) studied soil compaction as a function of penetration resistance at a constant water content (i.e., field capacity) and found that it was increased with the increase of soil bulk density and silt plus clay content. Likewise, Soane and Van Ouwerkerk (1994) stated that compaction can be measured or assessed by the change in many of soil properties, e.g. bulk density; void ratio and pore-size distribution. The state of compaction, is expressed by penetration resistance in some cultivated soils of Fayoum governorate.

MATERIALS AND METHODS

The current work was conducted on 24 farms (14 in Tamia and 10 in Fayoum districts, El-Fayoum governorate). These farms were chosen to represent three levels of productivity; that are relatively high, moderate and poor crop yield. In these farms, soil samples from the different depth, of the representative soil profiles were collected. In each farm penetration resistance was determined at the different depths of the soil profile, very close to each of sampling sites, using hand penetrograph penetrometer, as described by **(Klute 1986).** Also, the crop yield in each farm was determined via questionnaire sheet answered by farmers and checked by the agricultural administration staff in each area. Consequently, the relative crop yield in each farm was calculated as follows:

$$Yr = \frac{\text{Mean estimated yield of the cultivated crop}}{\text{The recorded maximum yield of the same crop all over El - Fayoum governorate}} \times 100$$

The collected soil samples were dried, gently crushed and divided into two parts, the first was preserved for aggregate analysis, while the 2nd part was sieved through a 2 mm sieve, and used for the determination of the relevant chemical and physical properties of the studied soils using the standard methods described by (Klute 1986) and (Richards 1954).

RESULTS AND DISCUSSION

Properties of the studied soils:

The basic soil properties of the chosen farms representing Tamia and Fayoum districts are presented in Table (1) & (2).

Textural classes of the different layers of profiles representing such soils are ranging from the almost coarse, i.e. loamy sand to the fine one, i.e. clayey texture. However, from the stand point of soil texture, the chosen farms, except few cases can roughly grouped into two categories; the first is characterized by relatively coarse texture and homogeneous soil profiles e.g. farms represented by profiles No. 1, 7 and 13. Meanwhile, the second category includes farms characterized by alternating relatively coarse, i.e. loamy sand, sandy loam and relatively finer textured layers i.e. sandy clay loam and clayey layers (profiles No. 2,3,5,6 and 12).

In this context, it is worthwhile to mention that field inspection indicated that the productivity of farms belonging to the first category, i.e. those characterized by their relatively coarse texture and homogeneous soil profiles (No. 1,7 and 13) are relatively higher compared to those of the second category (No. 3,5,6,12&14).

Likewise, it is evident that the textural classes of the different layers of profiles of Fayoum area.

Table (1) Basic soil properties of the studied farms

District	Farm No.	Soil depth (cm)	Coarse%	Fine%	Silt	Clay	Textural class*	O.M%	B. D. Mg.m-3	Total porosity%	P.R (MPa)at 20%(Ww)of A.W
(1) Tamia	1	0-40	63.36	10.40	17.30	8.94	S. L	0.87	1.29	51.32	1.20
		40-150	63.25	10.75	12.00	14.00	S. L	nd	1.30	50.94	1.24
	2	0-25	58.05	19.95	5.75	16.25	S. L	0.57	1.32	50.19	1.75
		25+	45.45	16.45	15.35	22.75	S. C. L	nd	1.44	45.66	2.18
	3	0-30	32.55	22.95	19.60	24.90	S.C. L	0.42	1.35	49.06	2.20
		30-35	53.70	12.90	17.80	15.60	S.L	nd	1.45	45.28	2.90
		35-40	47.80	10.90	22.50	18.80	S.L	nd	1.44	45.66	2.95
		40-60	43.70	18.05	17.80	20.45	S.C.L	nd	1.49	43.77	2.92
		60+	48.60	18.50	16.90	16.00	S.L	nd	1.48	44.15	2.80
	4	0-20	25.80	24.80	11.70	37.7	S.C	0.60	1.28	51.70	1.06
		20-40	25.90	27.50	13.00	33.60	S. C. L	nd	1.32	50.19	1.09
		40+	36.30	20.20	5.10	38.40	S. C	nd	1.38	47.92	1.29
	5	0-15	29.50	21.30	11.20	38.00	S. C	0.42	1.39	47.55	1.74
		15-50	32.00	23.10	11.50	33.40	S. C. L	nd	1.40	47.17	1.79
		50-150	30.10	17.20	9.50	43.20	S. C	nd	1.44	45.66	1.83
		150+	56.90	16.30	8.70	18.10	S. L	nd	1.40	47.17	2.06
	6	0-55	24.60	14.40	20.00	41.00	Clay	0.20	1.48	44.15	2.65
		55-125	29.00	16.60	12.00	42.40	S. C	nd	1.50	43.40	3.00
		125+	2.00	9.00	26.70	62.30	Clay	nd	1.50	43.40	3.06
	7	0-20	58.71	24.56	9.72	7.01	L.S	1.27	1.23	53.58	1.10
		20-40	60.43	19.38	7.81	12.38	S. L	nd	1.27	52.08	1.14
		40-60	64.76	18.11	5.02	12.11	L.S	nd	1.32	50.19	1.18
		60+	56.72	26.82	9.59	6.87	L.S	nd	1.40	47.17	1.21

cont. table (1)

District	Farm No.	Soil depth (cm)	Coarse%	Fine%	Silt	Clay	Textural class *	O.M%	B. D. Mg.m-3	Total porosity%	P.R (MPa)at 20%(Ww)of A.W
(1) Tamia	8	0-20	61.67	20.37	10.34	7.62	L.S	0.49	1.50	43.40	2.31
		20-40	53.43	30.68	6.81	9.08	L.S	nd	1.52	42.64	2.34
		40-60	63.16	22.01	5.07	9.76	L.S	nd	1.55	41.51	2.49
		60-80	67.98	16.73	9.01	6.28	L.S	nd	1.57	40.75	2.52
		80+	84.90	5.23	2.62	7.26	sand	nd	1.68	36.60	2.81
	9	0-20	59.20	14.80	13.10	12.90	S. L	0.87	1.35	49.06	2.01
		20-40	51.87	21.57	13.39	13.17	S. L	nd	1.44	45.66	2.12
		40-60	62.05	18.75	7.30	11.90	S. L	nd	1.45	45.28	2.15
		60+	60.77	17.47	8.59	13.17	S. L	nd	1.48	44.15	2.17
	10	0-20	45.61	35.06	12.22	7.11	L.S	0.36	1.50	43.40	1.65
		20-40	52.10	27.80	6.55	13.55	S. L	nd	1.50	43.40	2.85
		40-80	42.10	30.10	14.00	13.80	S. L	nd	1.55	41.51	2.90
	11	0-20	38.97	33.17	12.84	15.02	S. L	1.69	1.25	52.83	1.22
		20-40	41.37	28.67	10.24	19.72	S. L	nd	1.32	50.19	1.28
		40-60	67.52	15.82	6.04	10.62	L.S	nd	1.32	50.19	1.31
	12	0-20	25.23	30.48	25.96	18.33	S. L	0.51	1.48	44.15	2.75
		20-40	1.35	9.56	16.49	72.60	Clay	nd	1.50	43.40	3.05
		40-60	1.35	17.49	23.72	57.44	Clay	nd	1.50	43.40	3.12
	13	0-20	41.15	27.70	18.66	12.49	S. L	1.35	1.25	52.83	1.34
		20-40	59.97	18.07	7.44	14.52	S. L	nd	1.30	50.94	1.35
		40-60	59.50	21.30	8.50	10.70	S. L	nd	1.32	50.19	1.38
		60+	50.50	21.90	9.05	18.55	S. L	nd	1.34	49.43	1.41
	14	0-20	59.35	18.65	13.60	8.40	S. L	0.71	1.44	45.66	2.14
		20-40	38.42	26.52	10.39	24.67	S.C. L	nd	1.46	44.91	2.16
		40-60	41.18	34.03	12.46	12.33	S. L	nd	1.48	44.15	2.25
		60+	51.90	20.20	8.00	19.9	S. L	nd	1.50	43.40	2.26

Table (2) Basic soil properties of the studied farms

District	Farm No.	Soil depth (cm)	Coarse%	Fine%	Silt	Clay	Textural class*	O.M%	B. D. Mg.m-3	Total porosity%	P.R (MPa)at 20%(Ww)of A.W
(2) Fayoum	15	0-20	4.28	29.88	16.66	49.19	Clay	0.49	1.32	50.19	1.95
		20-40	3.94	14.28	34.42	47.36	Clay	nd	1.36	48.68	2.15
		40-60	23.63	20.37	10.37	45.64	Clay	nd	1.39	47.55	2.18
		60+	9.25	37.23	4.02	49.50	S.C	nd	1.42	46.42	2.20
	16	0-20	80.58	9.23	3.53	6.65	Sand	0.6	1.50	43.40	2.07
		20-40	75.55	8.24	9.86	6.36	L.S	nd	1.50	43.40	2.13
		40-60	69.12	10.45	8.80	11.63	S.L	nd	1.48	44.15	2.19
		60+	73.72	10.22	2.94	13.12	S.L	nd	1.48	44.15	2.21
	17	0-20	77.20	5.18	2.82	14.80	S.L	0.71	1.42	46.42	0.91
		20-40	92.54	2.42	2.57	2.47	sand	nd	1.44	45.66	0.99
		40-60	92.11	2.86	2.56	2.46	sand	nd	1.46	44.91	1.00
	18	0-20	81.70	12.92	3.42	1.96	sand	0.24	1.52	42.64	2.08
		20-40	85.81	7.43	3.45	3.31	sand	nd	1.55	41.51	2.21
		40-60	66.35	10.08	3.36	20.21	S. C. L	nd	1.43	46.04	2.30
		60+	78.26	14.54	3.67	3.53	sand	nd	1.55	41.51	2.32
	19	0-20	40.88	24.33	22.51	12.28	S. L	1.21	1.32	50.19	1.10
		20+	34.62	35.32	22.64	7.42	S. L	nd	1.38	47.92	1.14
	20	0-20	40.31	37.76	12.32	9.61	L.S	0.96	1.38	47.92	2.10
		20-40	28.73	40.38	23.01	7.88	S. L	nd	1.40	47.17	2.45
		40+	32.31	40.46	12.47	14.76	S. L	nd	1.42	46.42	2.03
	21	0-20	35.53	32.18	22.56	9.73	S. L	0.42	1.43	46.04	2.54
		20-40	45.48	30.53	14.66	9.33	S. L	nd	1.47	44.53	2.59
	22	0-30	38.09	6.84	22.04	33.03	C.L	0.34	1.37	48.30	2.27
		30-100	36.36	5.81	22.22	35.61	C. L	nd	1.45	45.28	2.25
		100+	31.26	15.16	20.72	32.86	S. C. L	nd	1.48	44.15	2.30
	23	0-15	41.1	5.6	19.9	33.4	S. C. L	0.17	1.36	48.68	2.58
		15-40	42.07	5.02	20.34	32.57	S. C. L	nd	1.39	47.55	2.94
		40-75	47.46	12.46	12.52	27.56	S. C. L	nd	1.40	47.17	3.05
		75-100	65.92	19.42	4.98	9.68	L.S	nd	1.50	43.40	2.56
		100+	61.98	18.84	12.19	6.99	L.S	nd	1.50	43.40	2.66
	24	0-40	8.51	10.16	24.37	56.96	Clay	1.13	1.28	51.70	1.08
		40-110	63.56	19.21	6.32	10.91	L.S	nd	1.36	48.68	1.12

* S.L = sand, S.C.L = sand clay loam, S.C = sandy clay, L.S = loamy sand, C.L = clay loam, PR=penetration resistance, BD=Bulk density, O.M=Organic matter, nd=not detected.

As for, the values of bulk densities of the different soil depths of Tamia area Table (1) shows that they ranged from 1.23 Mgm-3 to 1.55 Mgm-3. Exceptional being the deepest layer of profile No. 8, in which bulk density reached 1.68 Mg.m-3 due to the sandy nature of such a layer. It is also noticeable that the values of soil bulk density of the sub-surface soil layer i.e. below 50 cm depth, ranged from 1.38 Mg.m-3 to 1.55 Mgm-3, indicating high degrees of compactness of such layers. Also the values of porosity of such soils ranged from 36.60% to 52.83%. As for Fayoum area, Table (2) proves that the values of soil bulk density are ranged from 1.28 to 1.55 Mg.m-3, and exhibited an increasing trend with soil depth. Obviously these values seem to be related to the textural class of the soil. That is when the soil texture is coarse bulk density tends to be high and vice-versa.

In the present study, penetration resistance tests using penerometer, was taken as an indicator of soil compaction in the study area. Since soil penetration resistance is strongly dependant on soil water content, soil samples were taken, at time of conducting penetration tests, very close to the penerometer cone, from each of the tested depth. In such samples soil moisture content was determined to eliminate the influence of the variations of soil moisture in the tested depths on the values of penetration resistance (PR), the measured values of PR and their corresponding values of moisture content were statistically correlated, and the obtained regression formula was used to find out the adjusted PR values for the different depths at an equal value of soil matric potential. The chosen matric potential was 20% of the determined available water for each soil depth. The adjusted values of PR for the two studied areas are given in Table (1) & (2).

In case of Tamia area obtained results, Table (1) prove that the values of PR of the different soil depths ranged from 1.06 to 3 MPa. It is also evident that such values increased with depth, indicating high compactness of the deeper depths, most probably due to the fact that the frequency and intensity of tillage operation and hence their compacting effect increase with depth.

As for Fayoum area, Table (2) indicates a nearly similar trend to that manifested for Tamia area. Generally the obtained values of penetration resistance for the two areas under study indicate the relative difficulty of root – elongation through such soils and are greatly influenced by compaction. In this respect, Taylor and Ratliff (1969) found that the elongation rates of cotton and peanut top roots progressively decreased with increasing PR. they also found that a PR value of 0.7 MPa reduced the elongation of cotton roots by 50% while a value of 2 MPa was required to reduce peanut root elongation rate by 50%.

Relationships between PR and soil organic matter:

It is well established that depletion of organic matter content in soil can influence the characteristics of structural form by changing their sensitively to stress, i.e. the structural stability and hence the compatibility of soils. Therefore, in the current work the relationship between the organic matter content and the adjusted PR to do this the weighed values of the adjusted PR and corresponding weighed values of soil porosity up to 80 cm, i.e. effective root-zone depth, given in Table (3) and illustrated by Fig. (1), were statistically correlated highly significant correlations were obtained between the two variables. Therefore, regression analysis was calculated and the obtained formula was as follows:

$$y = -1.157x + 2.765 \ldots\ldots\ldots (1)$$

Where:
y= penetration resistance, (MPa).
$X_{(1)}$= O.M (%).

The obtained equation proves that increasing soil organic matter% (SOM) up to 0.5, 1 and 1.5%, results in reduction in soil strength by 21, 42 and 62%, respectively. This effect could be ascribed to the organic fragments of decomposed crop residues, with sizes ranging from a few microns to a few millimeters, which are generally supposed to induce weak sites and to increase soil porosity. Also, increasing SOM encourages the formation and stability of soil aggregates with consequent decrease in soil bulk density and hence decreasing soil strength (Ekwue, 1990).

Relationships between PR and soil porosity:

Due to the fact that soil compaction can influence crop growth and yield by changing soil structure and in turn soil porosity, with consequent impact on infiltration, drainage, aeration and nutrient uptake, therefore the relationship between PR and soil porosity was evaluated. To do this the weighed values of the adjusted PR and corresponding weighed values of soil porosity up to 80 cm, i.e. effective root-zone depth, given in Table (3) and illustrated by Fig. (2), were statistically correlated. Highly significant correlations were found between the two variables, thereby regression analysis was carried out and the obtained formula was as follows:

$$y = -0.141x + 8.480 \ldots\ldots\ldots. (2)$$

Where:
y= penetration resistance, (MPa).
$X_{(2)}$= Total porosity (%).

The formula indicates; within the valid range which lies between 35 and 58%; that every 5% increase in total porosity of soil, results in a decrease of in soil strength by 0.7 (MPa). This behavior could be attributed to the fact that soil strength is largely dependent on compactness, i.e. the extent to which compaction processes have influenced the packing of the constituent solid parts of the soil fabric. In other words, as the volume of packing increases, i.e. porosity increases the number of cracks or other types of structure weakness increases and consequently the strength decreases. These findings are in quite agreement with those arrived by Carter (1990) and Guerif (1994).

3.4. Relationships between PR and crop production in the study area:

In the current work, the status of productivity was expressed in relative term, i.e. the current, productivity on average as a percentage of the average recorded productivity which may represent non-degraded soils all over the governorate. To do this, the yield of each of cultivated crop was estimated via interviews and discussions with farmers and checking the attained values of crop yield with the Staff members of the Agricultural demonstrators in each district.

In this context, the prevailing crops in the two studied areas are wheat, olive, cotton, sugar beet, sorghum, sunflower, barely and alfalfa.

Table (3) values of relative yield and the corresponding weighed values of soil properties up to 80 cm depths of the studied farms

District	Farm No.	P.R (MPa)at 20%(Ww)*of A.W	Total porosity%	**O.M%	% Yield
(1) Tamia	1	1.22	51.13	0.87	85.71
	2	2.05	47.08	0.57	67.86
	3	2.62	46.06	0.42	25.00
	4	1.18	49.43	0.60	76.19
	5	1.80	46.67	0.42	68.57
	6	2.76	43.92	0.20	15.24
	7	1.16	50.75	1.27	86.96
	8	2.42	42.08	0.49	21.73
	9	2.11	46.04	0.87	73.33
	10	2.58	42.45	0.36	33.44
	11	1.28	50.85	1.69	83.33
	12	2.84	40.83	0.51	19.04
	13	1.37	50.85	1.35	82.61
	14	2.20	44.53	0.71	71.08
(2) Fayoum	15	2.12	48.21	0.49	63.82
	16	2.15	43.77	0.60	60.28
	17	0.98	45.47	0.71	82.79
	18	2.23	42.92	0.24	10.00
	19	1.13	48.49	1.21	89.86
	20	2.15	46.98	0.96	70.91
	21	2.58	44.91	0.42	8.50
	22	2.26	46.42	0.34	58.16
	23	2.90	47.33	0.17	31.22
	24	1.10	50.19	1.13	88.10

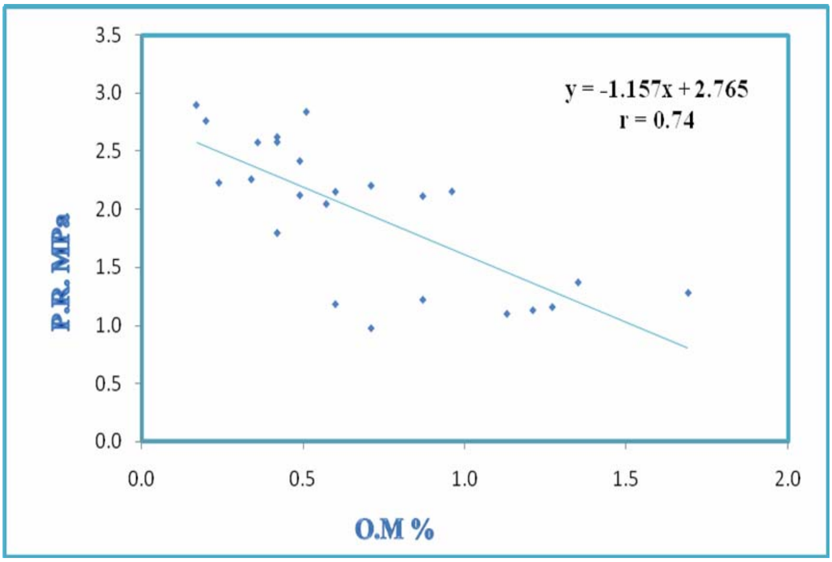

Fig (1) Relationship between O.M (%) and P.R. (MPa)

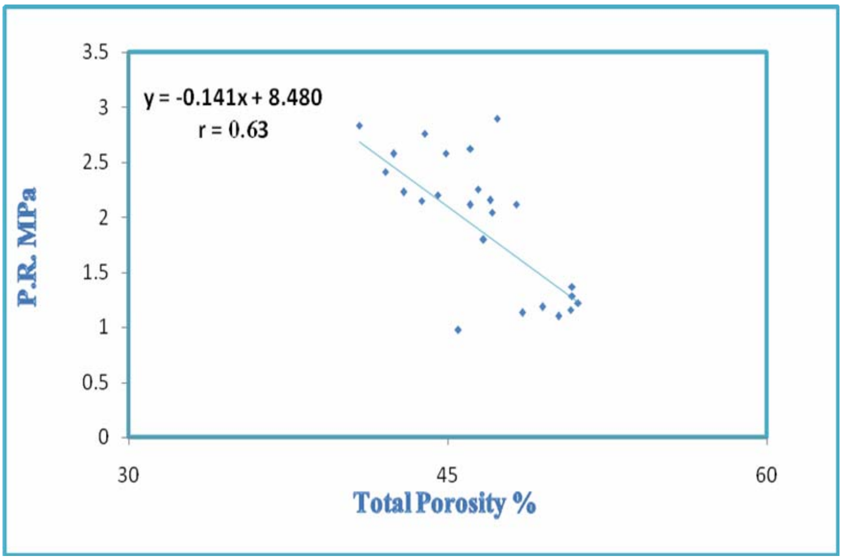

Fig (2) Relationship between total porosity (%) and P.R. (MPa)

Thereafter, the relative soil productivity in each farm, expressed by the values of relative yield (Yr) was calculated as follows:

$$Yr = \frac{\text{Mean estimated yield of the cultivated crop}}{\text{The recorded maximum yield of the same crop all over El - Fayoum governorate}} \times 100$$

The obtained data of the relative yield and the corresponding weighed values of the penetration resistance up to 80 cm depth of the profile representing each farm were statistically correlated. The obtained results indicated highly significant negative, given in Fig.(3), relationship between the two variables and the obtained formula was as follow :

$$y = -38.37x + 132.6 \ldots\ldots. (3)$$

Where:

y=relative yield (%) and $x_{(3)}$= penetration resistance, (MPa).

This equation reveals a linearly negative relationship between soil productivity and penetration resistance of the soil Fig(3). This behavior could be attributed to the adverse impact of soil compaction on the supply of water, oxygen and nutrients, with consequent limited root growth. The obtained relation indicates that as the PR of soil increased up to 2.5 MPa, the crop yield decreased by 50%, i.e. uneconomical yield. This conclusion goes hand in hand with those reported by Taylor (1971) and Hakansson and Voorhees (1998) who stated that the value of 2 - 2.5 MPa is the critical penetration resistance beyond which plant root elongation is severely restricted.

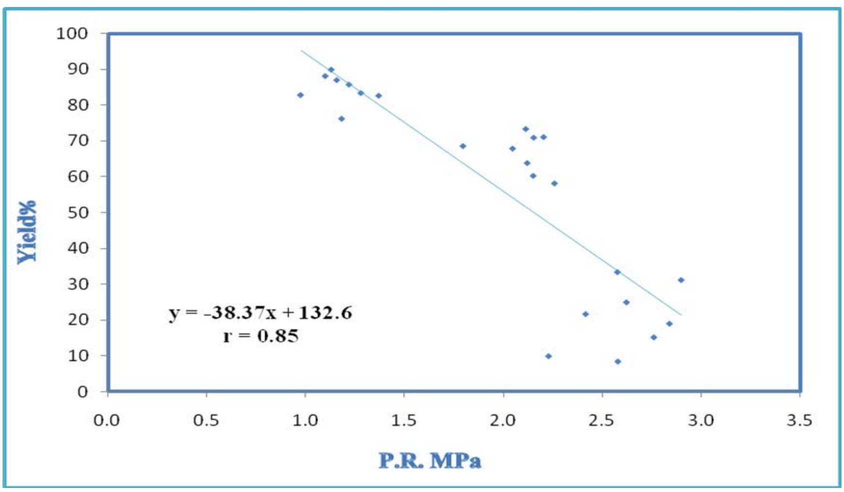

Fig (3) relationship between P.R (MPa) and relative yield(%)

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تداعيات أندماج التربة على أراضى وإنتاجية المحاصيل فى محافظة الفيوم

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تم أختيار عدد 24 مزرعة منها 14 مزرعة فى مركز طامية و10 مزارع فى مركز الفيوم بمحاظة الفيوم مختلفة فى خصائص التربة وعمليات الإدارة الزراعية. وأشارت النتائج المتحصل عليها لمقاومة الأختراق (PR) إلى أنها مرتفعة نسبيا ويتراوح قيمتها بين 1,06 و 3 ميجا بسكال بمنطقتى الدراسة. وهذا يشير إلى الصعوبة النسبية لأختراق جذر النبات خلال التربة. وتشير الدراسة أيضا إلى علاقات سالبة ذات معنوية عالية بين مقاومة الأختراق(PR) وكلا من المادة العضوية للتربة ومسامية التربة.

أظهرت هذه الدراسة أيضا وجود علاقة سالبة ذات معنوية عالية بين إنتاجية المحصول وقيم مقاومة الأختراق (PR) وهذا يرجع إلى الإمداد المحدود للماء والأوكسجين والعناصر الغذائية. مما يؤدى إلى نمو محدود للجذر فى الأراضى المندمجة.