RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

4.1 Soil structure:

Soil structure is defined as the arrangement and orientation of individual soil particles. The influence of the applied composts and their addition rates of some aspects of soil structure can be discussed under the following subheadings:

4.1.1. Soil bulk density (D_b):

Data in Table (3) and Figs (2, 3 and 4) show the effect of levels of composted materials, soil moisture depletion and biofertilization treatments on soil bulk density (Db) of Maryut calcareous soil. For the top soil layer (0-10 cm), the data indicated that the composting sheep dung was superior for decreasing (Db) than the farmyard and town refuse, where the magnitude of decrease relative to the control amounted 6.3, 4.2 and 2.1 %, respectively. Such effect was more pronounced with increasing the application rate of these composts. These results were concomitant with Chen and Avnimelech (1986), El-Maghraby (1997) and El-Sersawy and Khalil (1991).

Regarding the effect of soil moisture depletion (Db) the data point out the irrigation at 50 % depletion from soil available water significantly decreased (Db) better than the 70 %. This trend might rendered to the suitability of moisture condition, which enhances the root system development and microbial activity. Thereby encourages the aggregation process and (Db) decrease. Moreover, the values of (Db) under biofertilization treatment was lower than those under control i.e., without biofertilization, where mean values of (Db) amounted 1.37 and 1.40-g.cm^3, pertaining to former and the latter respectively.

Regarding the second layer (10-20 cm), the obtained data was illustrated on Table (3) and Figs (2, 3 and 4) indicated that the

Table (3): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil bulk density (g/cm^3).

Biofertilization	Depletion levels	Depth (cm)	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	0-10	1.38	1.36	1.35	1.34	1.31	1.30	1.29	1.36	1.32	1.30
		10-20	1.48	1.46	1.45	1.43	1.44	1.42	1.41	1.40	1.38	1.36
		20-30	1.55	1.54	1.53	1.51	1.53	1.51	1.49	1.46	1.43	1.41
	70 %	0-10	1.46	1.44	1.43	1.42	1.43	1.42	1.41	1.34	1.32	1.31
		10-20	1.53	1.51	1.50	1.49	1.48	1.46	1.45	1.47	1.46	1.38
		20-30	1.57	1.56	1.54	1.53	1.53	1.51	1.50	1.55	1.51	1.47
Without	50 %	0-10	1.41	1.38	1.37	1.36	1.32	1.31	1.30	1.38	1.35	1.32
		10-20	1.50	1.48	1.46	1.45	1.47	1.45	1.44	1.45	1.42	1.39
		20-30	1.59	1.56	1.55	1.53	1.54	1.52	1.51	1.51	1.47	1.45
	70 %	0-10	1.47	1.46	1.45	1.43	1.44	1.43	1.42	1.35	1.34	1.33
		10-20	1.54	1.53	1.52	1.50	1.49	1.47	1.46	1.52	1.49	1.45
		20-30	1.60	1.57	1.56	1.54	1.55	1.53	1.52	1.57	1.54	1.52

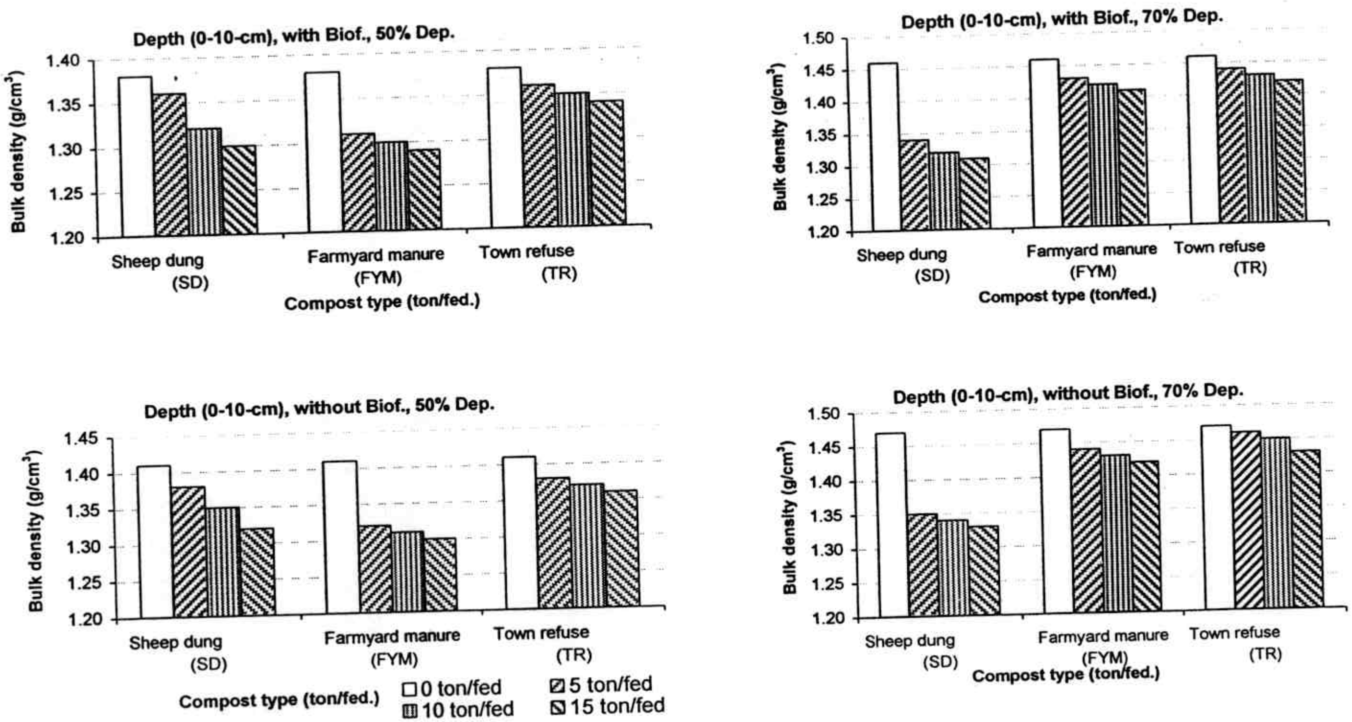


Fig. (2): Effect of composting types & rates, irrigation water depletions and biofertilization on bulk density (first depth) of Maryut calcareous soil.

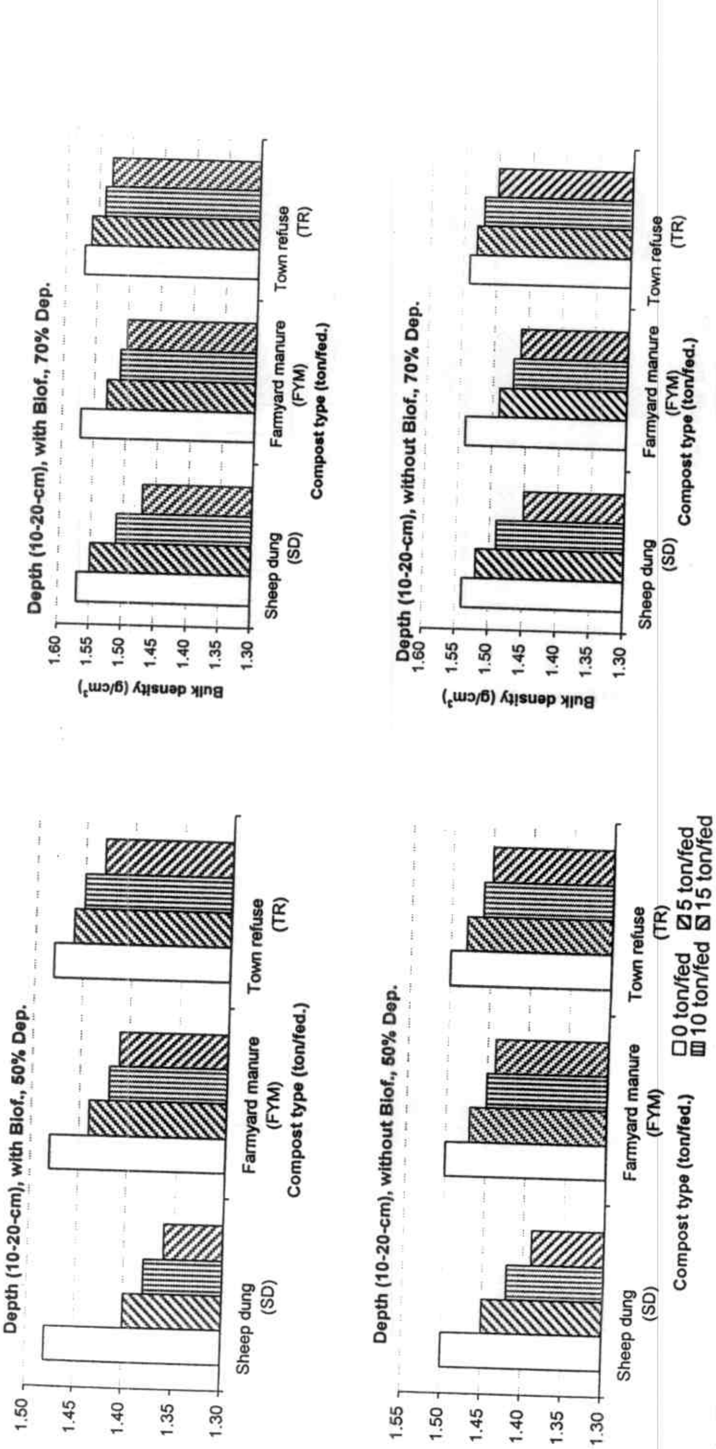


Fig. (3): Effect of composting types & rates, irrigation water depletions and biofertilization on bulk density (second depth) of Maryut calcareous soil.

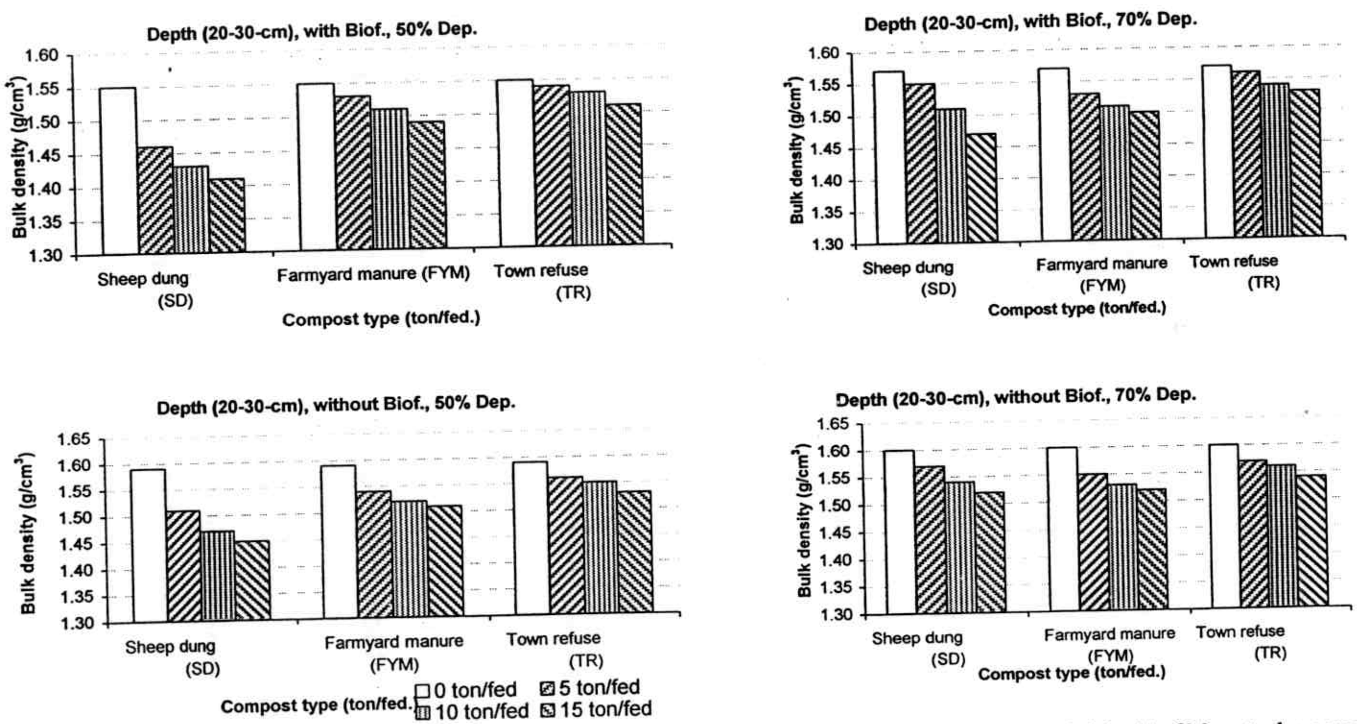


Fig. (4): Effect of composting types & rates, irrigation water depletions and biofertilization on bulk density (third depth) of Maryut calcareous soil.

sheep dung is more effective in decreasing (Db) as compared to the other composting types. The magnitude of decrease reached 4, 3 and 1 % for sheep dung, farmyard and town refuse, respectively. Concurrently, the application rates of composts take the same trend but with different magnitudes. Whereas, at 5-ton/fed. application rate, the decreasing in (Db) amounted 3.3, 2.6 and 0.7 %. At 10-ton/fed. Application rate, this decrease reached 4.6, 4 and 2 % while at 15-ton/fed. Application rate the highest decrease obtained was 7.2, 4.6 and 2.6 % associated to the SD, FYM and TR composts, respectively. The data also revealed the tendency of decrease in (Db) under the 50 % depletion level than 70 % depletion level. Furthermore, the data indicated that the use of biofertilizer in calcareous soil enhanced the decrease effect of (Db) which helped the composts and soil water depletion (at 50 %) in diminishing (Db) values as compared with the unbiofertilizered soil.

Concerning the third soil depth (20-30 cm) the data in Table (3) and Figs (2, 3 and 4) point out that the compost affected on (Db) as nearly similar to that in the surface two layers, i. e. the high decrease in (Db) is due to sheep dung followed by farmyard and town refuse. However, the percent of decrease in soil (Db) of this depth was of low magnitude as compared with the above two layers. The superiority of sheep dung to decrease (Db) comparing the other two composts renders to its fineness (Table, 2) that lead to more in homogenous distribution and migration of its constituents between soil particles, subsequently, more friability condition low soil weight in the unit volume, i.e. decrease (Db).

The statistical analysis (ANOVA) emphasized the significance of the experimental treatments and their interactions on soil (Db), Table (4). The results indicated the high significant effect

Table (4): Values of LSD of soil bulk density as affected by the experimental variables.

Biofertilization	Depth (cm)	D	T	R	D X T	D X R	T X R	T X D X R
With	0 - 10	0.0008 **	0.0004 ***	0.0002 ***	0.0004 ***	0.0002 ns	0.0002 ***	0.0002 ***
	10 - 20	0.0005 **	0.0007 ***	0.0004 ***	0.0007 ns	0.0004 ns	0.0004 ***	0.0004 ns
	20 - 30	0.0002 *	0.0002 ***	0.0003 ***	0.0002 **	0.0003 ns	0.0003 ***	0.0003 ns
Without	0 - 10	0.0022 *	0.0004 ***	0.0001 ***	0.0004 ***	0.0001 ns	0.0001 ***	0.0001 ***
	10 - 20	0.0005 *	0.0007 *	0.0003 ***	0.0007 ns	0.0003 ns	0.0003 *	0.0003 ns
	20 - 30	0.0009 ns	0.0006 **	0.0003 ***	0.0006 *	0.0003 ns	0.0003 *	0.0003 ns

Where:

N = 144 *Sig. 0.05 ** Sig. 0.01 ***Sig. 0.005

D = depletion level. D x T = interaction between depletion and compost type.

T = compost type. D x R = interaction between depletion and compost rate.

R = compost rate. T x R = interaction between both compost type and rate.

T x D x R = interaction between the three variabls, i.e; compost type, depletion level and compost rate.

of compost types (T), rates (R) while it was quietly significant one pertaining the effect of soil water depletion levels (D).

Organic carbon is considered as an end product of organic compost decomposition under different soil treatments. So, the values of organic carbon obtained at the end of the experiment were presented in Table (5).

The data indicated that farmyard and town refuse composts at different application rates surpassed the sheep dung compost in achieving higher organic carbon percentages. The application of 50 % depletion level especially under soil biofertilization tends to increase this percent of organic carbon. So, the idea of testing the interrelation between some soil physical properties and the organic carbon percentages under different organic compost types was carried out. The correlation and regression statistical analysis was done between soil bulk density at three soil depths and the organic carbon percentages of each compost type. Concurrently, the good correlation and regression relations were found between the organic carbon percent of each compost types and the (Db) values of soil treatments. The correlation coefficients and regression equations, which control these relations were presented in Table (6). The results pointed out the high significant negative correlation between organic carbon and soil (Db) in all soil depth except the underneath soil depth (10-20 and 20-30 cm) under sheep dung compost. This trend could be attributed to the high organic matter content in the upper depth of the composted soil and also, the fine fractions of such compost material can not able to migrate to the underneath layers. This is due on one hand to greater compost fine fractions, i.e., (at 0.2, 0.1 and <0.1-mm sizes) under sheep dung compost and on the other

Table (5): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on organic carbon percent of soil.

Biofertilization	Depletion levels	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
			Addition rates (ton/fed.)								
			5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	0.20	0.32	0.77	0.98	0.30	0.75	0.87	0.27	0.73	0.88
	70 %	0.23	0.30	0.74	0.96	0.28	0.72	0.78	0.25	0.54	0.65
Whitout	50 %	0.22	0.30	0.40	0.85	0.28	0.65	0.84	0.26	0.60	0.82
	70 %	0.24	0.28	0.72	0.84	0.26	0.70	0.73	0.24	0.54	0.57

Table (6): The correlation and regression analysis between soil bulk density at different depth and organic carbon percentages.

Type of composts	Soil depth (cm)	Correlation coefficient	Regression equation
Town refuse	0 – 10	-0.798**	Y = 1.495 – 0.161X
	10 – 20	-0.872**	Y = 1.558 – 0.129X
	20 – 30	-0.892**	Y = 1.586 – 0.072X
Farmyard manure	0 – 10	-0.916**	Y = 1.532 – 0.261X
	10 – 20	-0.884**	Y = 1.510 – 0.090X
	20 – 30	-0.597*	Y = 1.548 – 0.044X
Sheep dung	0 – 10	-0.878**	Y = 1.380 – 0.071X
	10 – 20	-0.489	------------------------
	20 – 30	-0.464	------------------------

Where, Y is the bulk density of each soil depth and X is the corresponding soil organic carbon content.

* Significant at 0.05 level.

** Significant at 0.01 level.

*** Significant at 0.005 level.

hand to the greater bulk density of farmyard and town refuse Table (2).

The computed regression equations concluded that increasing organic carbon by 0.1 % led to a decrease in soil (Db) of 0.026, 0.016 and 0.007 $g.cm^3$ associated with farmyard, town refuse and sheep dung composts respectively. These results are matched with those reported by Khaleel et al. (1981) whereas, they mentioned that highly significant correlation was found between the increase in soil organic carbon induced by manure application and the lowering in bulk density of the soil.

4. 1. 2. Soil porosity and pore size distribution:

a) Soil porosity:

The data in Table (7) clarified that the compost addition for calcareous soil of Maryut was more effective on increasing total porosity with priority of sheep dung, which led to 8.6 % increasing percent as compared with the control. The addition of farmyard and town refuse composts caused quiet increment on soil total porosity whereas, the magnitude of increasing amounted 6.5 and 4.2 % comparing with the control, respectively. The addition rates of each type of composts effectuated the improvement of soil total porosity under all types of composts.

A sensible increase was achieved in soil porosity by increasing the application rates of different composts indicating pronounced ameliorating soil structure. These results were concomitant with those reported by Giusquiani *et al.* (1995) and El-Sersawy (1996) as they observed that a liner relation between soil

Table (7): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil porosity.

Biofertilization	Depletion levels	Depth (cm)	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	0-10	40.51	41.24	41.66	42.10	43.78	44.11	44.54	41.38	43.16	44.61
		10-20	36.99	37.73	38.30	39.01	38.87	39.57	39.86	40.38	41.81	43.25
		20-30	35.41	35.97	36.39	37.08	36.39	37.22	37.64	39.79	40.42	41.11
	70 %	0-10	37.04	40.52	40.95	41.38	43.10	43.52	43.97	41.60	43.54	43.97
		10-20	34.84	37.02	37.87	38.30	37.45	38.30	38.72	38.30	39.57	40.83
		20-30	33.75	35.00	35.42	36.25	35.70	36.67	37.08	37.08	38.75	39.58
Without	50 %	0-10	38.21	40.37	40.95	41.52	42.96	43.39	44.11	40.38	41.81	43.25
		10-20	36.60	37.16	37.87	38.44	37.16	38.30	38.72	38.44	39.57	40.71
		20-30	33.73	35.00	35.42	36.39	35.70	36.53	37.09	36.05	38.61	40.39
	70 %	0-10	36.64	37.21	37.72	38.36	38.07	38.36	38.79	41.17	42.89	43.32
		10-20	34.47	35.03	35.46	36.17	36.68	37.30	37.87	35.32	36.74	38.44
		20-30	33.33	34.58	35.00	35.83	35.56	36.11	36.66	34.72	35.83	36.67

prosity and the compost application rates. It is generally obvious that, porosity of the soil depth (0–10 cm) showed the greatest modification followed by the other two depths, i. e., (10-20 and 20-30 cm).

In regard to the effect of irrigation water depletion on total porosity, the data in the same table revealed that the compost addition under 50 % depletion level surpassed the another one of 70 % depletion level in increasing total porosity of the soil. The magnitude of increase amounted 6 and 2 % as compared with the control for the former depletion and the latter one. This behavior could be attributed to the enhancement of soil aggregability subsequently soil porosity under the effect of first condition rather than the second one. These results are in accordance with those of Massoud (1972), Russell (1989), El-Sersawy *et al.* (1993), and El-Maghraby (1997).

Concerning the effect of biofertilization on total porosity, data shows increasing soil porosity due to biofertilization soil treatment amounted 5 %. Over the unbiofertilized soil, This trend may be rendered to promoting the media of calcareous soil with the specific beneficial bacterial strains, which produce many binding and cohesive materials such as enzymes, slimes, and polysaccharides. These materials enhance root growth, soil aggregate stability and consequently total porosity improvement, Haahtela *et al.* (1983), Amara (1994), and Abd El-Ghany *et al.* (1997).

It is worth to mention that, the interaction effect between compost types, especially at the highest application rate of manure (15 ton/fed.) and the depletion level of 50 % as well as using biofertilization led to high increase in total porosity of soil. Such increase amounted 10, 17 and 16 % for the first, second and third soil depths comparing with the control, respectively. The statistical analyses (ANOVA) in Table (8) emphasized also the significance in most cases of individual reactions for three soil depths whereas, the effect of compost type (T) and rate (R) was highly significant while depletion level (D) was quietly significant one. The data clarified that the compost type (T) was the most important factor affecting total porosity of the soil followed by the application rate (R) and the depletion level (D).

b) Soil pore size distribution:

The effect of the applied treatments on the size distribution of soil pores was presented in Table (9). The pore size distribution groups involved large pores (> 60 μm in diameter), medium pores (60 -10 μm in diameter), small pores (10 - 0.2 μm in diameter) and very small pores (< 0.2 μm in diameter). The data clarified that different types of composts were able to modify the percentages of soil large, medium and small pores against the control by varying increasing trends. The large pores increased with 10, 10 and 11 % under town refuse, FYM and sheep composts, respectively. The medium pores achieved an increase of 116, 131 and 123 % while the small pores achieved increment of 17,18 and 23 % in the same sequence. So, it could be concluded that FYM and sheep composts were superior than town refuse in affecting medium and small pores. On the contrary the effect of composting materials on large pore was, more or less similar. This trend could be attributed to the origin fertility and enrichment of the FYM and sheep composts than the town refuse. This led to more suitable reactions into the soil, which produced higher water stable aggregates, subsequently, soil pore spaces associated with the former two composts than the latter one.

Table (8): Values of LSD of soil porosity as affected by the experimental variables.

Biofertilization	Depth (cm)	D	T	R	D X T	D X R	T X R	T X D X R
With	0 - 10	2.064 *	0.9996 ***	1.22 **	1.731 ***	1.725 ns	2.112 ns	2.987 ns
	10 - 20	1.5398 *	0.8115 ***	0.5471 ***	1.406 ns	0.7737 ***	0.9476 ***	1.34 ns
	20 - 30	1.314 ns	0.486 ***	0.4259 ***	0.8418 **	0.6024 ns	0.7377 ***	1.043 ns
Without	0 - 10	1.616 *	0.6896 ***	0.42 ***	1.194 ***	0.594 ns	0.7275 ***	1.029 ***
	10 - 20	1.53 *	0.7243 *	0.846 ***	1.255 ns	0.846 ns	0.846 **	0.846 ns
	20 - 30	0.825 *	0.5857 **	0.383 ***	1.014 **	0.4516 *	0.6634 ***	0.9382 *

Where:
N = 144
D = depletion level.
T = compost type.
R = compost rate.

*Sig. 0.05 ** Sig. 0.01 ***Sig. 0.005
D x T = interaction between depletion and compost type.
D x R = interaction between depletion and compost rate.
T x R = interaction between both compost type and rate.
T x D x R = interaction between the three variabls, i.e; compost type, depletion level and compost rate.

Table (9): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil pore size distribution percent (on volume basis).

Biofertilization	Depletion levels	Pore types	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	Large pores	9.10	9.52	10.08	10.30	9.56	10.15	10.45	9.60	10.40	10.55
		Medium pores	3.29	6.20	7.40	7.50	6.30	7.45	8.00	6.50	7.53	8.50
		Small pores	7.20	7.53	8.00	8.70	7.65	9.45	9.80	7.69	9.48	9.84
		Very small pores	19.16	17.63	17.08	16.50	16.40	16.39	15.25	16.09	15.43	14.81
	70 %	Large pores	8.77	9.19	9.75	9.97	9.23	9.82	10.12	9.27	10.07	10.22
		Medium pores	3.00	6.00	6.50	7.10	6.08	6.55	7.80	6.10	6.80	8.20
		Small pores	6.10	6.50	7.40	8.50	6.70	7.00	8.30	7.00	7.60	8.70
		Very small pores	20.04	17.72	17.04	16.41	17.95	16.64	15.62	17.91	16.55	14.95
Without	50 %	Large pores	6.70	8.12	8.53	8.75	8.16	8.60	8.90	8.20	8.85	9.00
		Medium pores	2.50	5.90	6.20	6.40	6.04	6.50	6.60	6.00	6.60	8.00
		Small pores	4.00	6.20	6.30	8.35	6.40	6.84	8.00	6.80	7.52	8.45
		Very small pores	22.50	19.19	19.00	18.48	18.17	17.47	16.48	18.06	17.00	15.97
	70 %	Large pores	6.70	6.97	8.38	8.60	8.00	8.45	8.75	8.05	8.70	8.85
		Medium pores	2.10	5.30	5.60	6.20	5.25	5.70	7.00	5.35	5.80	7.20
		Small pores	3.70	6.00	5.85	7.10	6.30	6.77	7.75	6.45	7.33	8.15
		Very small pores	23.06	19.98	19.42	18.93	18.57	17.55	16.65	18.40	17.95	16.00

Referring to the very small pores, the data reveal the tendency of decrease for the composted treatments comparing with the control, whereas, the decreasing percent reached to 13, 19 and 16 % for town refuse, farmyard and sheep dung composts, respectively. The promoting effect of composts on the large, medium and small pores, with consequent declining to the very small ones can be considered a desirable condition especially in compacted calcareous soil. Russell (1989) and Giusquiani *et al.* (1995) reported that small pores (10 – 0.2 μm) are necessary for water storage and bacterial growing and activity, medium pores (60–10 μm) are important for growing and activity of root hairs, large pores (> 60 μm) are essential for drainage and soil aeration especially in fine textured soil. Concerning the effect application rates of different composts on the pore size distribution the obtained data showed that these modification of pore size groups increases with increasing the applications rates of composts. The large pores were responded by increasing the application compost rate from 5 to 10-ton/fed. more than changing the rate from 10 to 15-ton/fed.. Where, the increase percent amounted to 9 and 4 % for the former condition and the latter one, respectively. The medium pores took another trend whereas the increasing rates of composts from 5 to 10 and 10 to 15-ton/fed. led to equal percent, i.e., 27 % increase at each increase of the application rate. The small pores behaved such as large ones but the modification percent of them amounted to 14 % whenever rate changed from 5 to 10-ton/fed. and 12 % when it changed from 10 to 15-ton/fed.. This indicates the positive response of calcareous soil pore spaces to the gradual organic compost additions. These results are matched with those reported by Sakr (1985), Omar (1990), Schulten and Leinweber (1991) and El- Sersawy (1997). The very small pores were decreased by gradual increase in the application rate of composts where, the decrease was by about to 3, 4 and 5 %, comparing with the control, associated with town refuse, FYM and sheep dung composts, respectively. These trends may reflect the extent of soil structure improvement due to the addition of different compost types and rates, which may be considered as an essential management practice of soil, El-Maghraby (1997) and Cook *et al.* (1979).

Regarding to the effect of water depletion on the distribution of pore size, the data in Table (9) indicated that under both depletion 50 or 70 % there are markedly increase in different size of soil pores i. e., (large, medium and small) compared with control. The magnitude of increase amounted, 11, 123 and 22 % for large, medium and small pores, respectively. While very small pores decreased by 16 % referring to the control. That high response of medium pores to both depletion treatments was similar to the effect of compost types and rates, where they were generally led to high increase in medium pores than the other ones. This in fact, is very important in calcareous soil due to the effect of such type of pores on growing and activity of root hairs, (Russell, 1989). In addition, Israelsen and Hansen (1962) reported that there are direct effects of pore size on soil productivity owing to their great influence on the movement of air, water and roots through the soil, as well as the water holding capacity. They added, when the pore size of a productive soil is reduced by 10 %, the movement of air, water and roots is greatly restricted and plant growth is very seriously impeded and vice-versa.

Regarding to the effect of biofertilization on different pore sizes the data in the same table clarified the importance of using this technique, especially when interacted with organic composts as a suitable manner for calcareous soil. The increasing percent in different pore spaces under the treatments of biofertilization surpassed the corresponding percent under the unbiofertilized ones, by 19, 30 and 20 % pertaining to large, medium and small pores, respectively. This trend could be described to the promoting effect of bacterial byproducts, enzymes and organic polymers on soil aggregation and root elongation subsequently, establishment of new pore size groups. The improvement in pore space quantities took the following descending order medium pores > small pores > large pores, which reflected soil structure amelioration under the effect of bio-organic treatments. These results are in agreement with those reported by El-Demerdash (1987), Pagliai and De-Nobili (1993) and El-Sersawy (1997).

The statistical analysis given in Table (10) emphasized the dependency of pore size distribution of soil on compost types (T), application rates (R) and irrigation water depletions (D).

4. 1. 3. Soil aggregation and aggregate stability:

The data in Tables (11, a and b) and Figs (5, 6 and 7) reveal the effect of organic composting types and rates, irrigation water depletion levels and biofertilizer application on water stable aggregate percentages of Maryut calcareous soil. The results clarified that the addition of different composts induce remarkable increase in the soil aggregate stability. However such effect vary according to the type of the composts. Sheep compost was superior than farmyard and town refuse. The increasing percent referred to the control amounted 58, 56 and 32 % for three types of composts, respectively. The increasing rates of different composts matched the percent of increase in soil water stable aggregates. The application rates of 5, 10 and 15-ton/fed.,

Table (10): Values of LSD of soil pore size distribution as affected by the experimental variables.

Biofertilization	Pore types	D	T	R	D X T	D X R	T X R	T X D X R
With	Large pores	0.0014 **	0.0013 ***	0.0018 ***	0.0013 ***	0.0018 ***	0.0018 ***	0.0018 ***
	Medium pores	0.0064 **	0.0027 ***	0.0036 ***	0.0027 ***	0.0036 ***	0.0036 ***	0.0036 ***
	Small pores	0.0049 **	0.0059 ***	0.0007 ***	0.0059 ns	0.0007 ns	0.0007 ***	0.0007 ***
	Very small pores	0.0117 **	0.0175 ***	0.0448 ***	0.0175 ***	0.0448 ***	0.0448 ***	0.0448 ***
Without	Large pores	0.0005 **	0.0002 ***	0.0004 ***	0.0002 ***	0.0004 ***	0.0004 ***	0.0004 ***
	Medium pores	0.0007 **	0.0003 ***	0.0005 ***	0.0003 ***	0.0005 ***	0.0005 ***	0.0005 ***
	Small pores	0.0014 **	0.0004 ***	0.0004 ***	0.0004 ***	0.0004 ***	0.0004 ***	0.0004 ***
	Very small pores	0.0000 **	0.0012 ***	0.0044 ***	0.0012 ***	0.0004 ***	0.0004 ***	0.0004 ***

Where:

N = 144 *Sig. 0.05 ** Sig. 0.01 ***Sig. 0.005

D = depletion level.
T = compost type.
R = compost rate.

D x T = interaction between depletion and compost type.
D x R = interaction between depletion and compost rate.
T x R = interaction between both compost type and rate.
T x D x R = interaction between the three variabls, i.e; compost type, depletion level and compost rate.

Table (11-a): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on water stable aggregate percentages of soil.

Depletion levels	Soil aggregate size fractions dia.(mm)	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
			Addition rates (ton/fed.)								
			5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
50 %	1.0 - 0.84	1.30	1.32	1.62	2.32	1.62	2.37	2.75	2.03	2.54	3.54
	0.84 - 0.50	0.62	1.25	1.39	1.47	1.25	1.33	1.41	1.06	1.22	1.14
	1.0 - 0.50*	1.92	2.57	3.01	3.79	2.87	3.70	4.16	3.09	3.76	4.68
	0.50 - 0.15	1.80	2.11	2.58	2.74	2.80	3.13	3.20	2.90	3.26	3.51
	0.15 - 0.10	1.50	2.19	2.69	2.96	2.69	3.19	3.45	2.75	2.96	3.22
	0.50 - 0.10**	3.30	4.30	5.27	5.70	5.49	6.32	6.65	5.65	6.22	6.73
70 %	1.0 - 0.84	0.97	1.05	1.16	1.27	1.56	1.90	2.45	1.79	1.85	2.80
	0.84 - 0.50	0.57	0.86	1.17	1.17	0.72	0.93	1.10	0.95	0.95	1.01
	1.0 - 0.50*	1.54	1.91	2.33	2.44	2.28	2.83	3.55	2.74	2.80	3.81
	0.50 - 0.15	1.28	1.31	1.71	2.26	2.36	2.56	2.73	2.14	2.27	2.32
	0.15 - 0.10	1.73	2.19	2.59	2.74	2.48	2.56	2.63	2.69	2.82	3.32
	0.50 - 0.10**	3.01	3.50	4.30	5.00	4.84	5.12	5.36	4.83	5.09	5.64

*1.0 - 0.50 = Sum {(1.0 - 0.84) + (0.84 - 0.50)} Macroaggregates
** 0.50 - 0.10 = Sum {(0.50 - 0.15) + (0.15 - 0.10)} Microaggregates
It divided to macro and microaggregates according to Ziegler and Sutherland (1985) and Aoyama et al. (1999)

Table (11-b): Influence of types and addition rates of compost materials and irrigation water depletion levels without biofertilization on water stable aggregate percentages of soil.

Depletion levels	Soil aggregate size fractions dia.(mm)	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
			Addition rates (ton/fed.)								
			5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
50 %	1.0 - 0.84	1.30	1.53	1.71	2.06	1.57	1.93	2.60	1.85	2.02	2.7
	0.84 - 0.50	0.55	0.88	1.24	1.26	0.96	1.13	1.79	0.98	1.36	1.8
	1.0 - 0.50*	1.85	2.41	2.95	3.32	2.53	3.06	4.39	2.83	3.38	4.51
	0.50 - 0.15	1.74	1.81	2.03	2.69	1.88	2.21	2.76	2.40	3.00	3.2
	0.15 - 0.10	1.33	1.40	1.90	2.00	1.90	2.10	2.30	2.07	2.04	2.5
	0.50 - 0.10**	3.07	3.21	3.93	4.69	3.78	4.31	5.06	4.47	5.04	5.70
70 %	1.0 - 0.84	0.56	1.40	1.75	1.98	1.33	1.40	2.00	1.45	1.60	2.26
	0.84 - 0.50	0.46	0.50	0.75	0.80	0.59	0.81	0.91	0.73	0.86	1.00
	1.0 - 0.50*	1.02	1.90	2.50	2.78	1.92	2.21	2.91	2.18	2.46	3.26
	0.50 - 0.15	1.18	1.52	1.72	1.80	1.70	1.83	1.90	1.97	2.00	2.10
	0.15 - 0.10	1.00	1.20	1.72	1.92	1.84	1.80	2.00	1.92	1.98	2.10
	0.50 - 0.10**	2.18	2.72	3.44	3.72	3.54	3.63	3.90	3.89	3.98	4.20

*1.0 - 0.50 = Sum {(1.0 - 0.84) + (0.84 - 0.50)} Macroaggregates

** 0.50 - 0.10 = Sum {(0.50 - 0.15) + (0.15 - 0.10)} Microaggregates

It divided to macro and microaggregates according to Ziegler and Sutherland (1985) and Aoyama et al. (1999)

of town refuse lead to an increase of 60, 111 and 151 % respectively. In case of farmyard manure and sheep compost, such increments reached to 110, 167 and 216 % and 135, 170 and 243, respectively. These results are concomitant with those reported by Unger and Stewart (1974), and Tisdall and Oades (1982) and Stevenson (1994), who concluded that the application of large quantities of organic amendments in form of cover crops and manures or composts can increase soil aggregation and improve soil structure. Regarding the effect of experimental treatments on the formation of macroaggregates (1.0 to 0.5 mm) and microaggregates (0.5 to 0.1 mm), the data in Table (11, a and b) and Figs (5, 6 and 7) show a tendency of increase in micro-aggregates with increasing compost quantity than the macro-aggregates, under any type of composts. However, sheep dung compost was the most effective one in forming micro-water stable aggregates followed by farmyard and town refuse. This trend may be ascribed to the narrow C:N ratio high root and growth, humic materials and root exudates which reacted as a cohesive agents between soil separates in the former compost than other ones. These components help in binding soil particles into structural units of stable aggregates, (Franken and Hurtmanns, 1985 and Stevenson, 1994). In addition, Tisdall and Oades (1982) reported that micro-aggregates are highly stable in soil and they in turn, become bound into macro-aggregates to give stable soil structure.

Concerning the tendency of water stable aggregates formation under depletion level treatments, i. e. (50 and 70 %) the data point out the interacting effect of composts and the applied water depletion level led to 86 and 52 % increase in total aggregate, receptively. This effect was more pronounced under the sheep dung and farmyard than town refuse especially at 50 % depletion level. The more fine

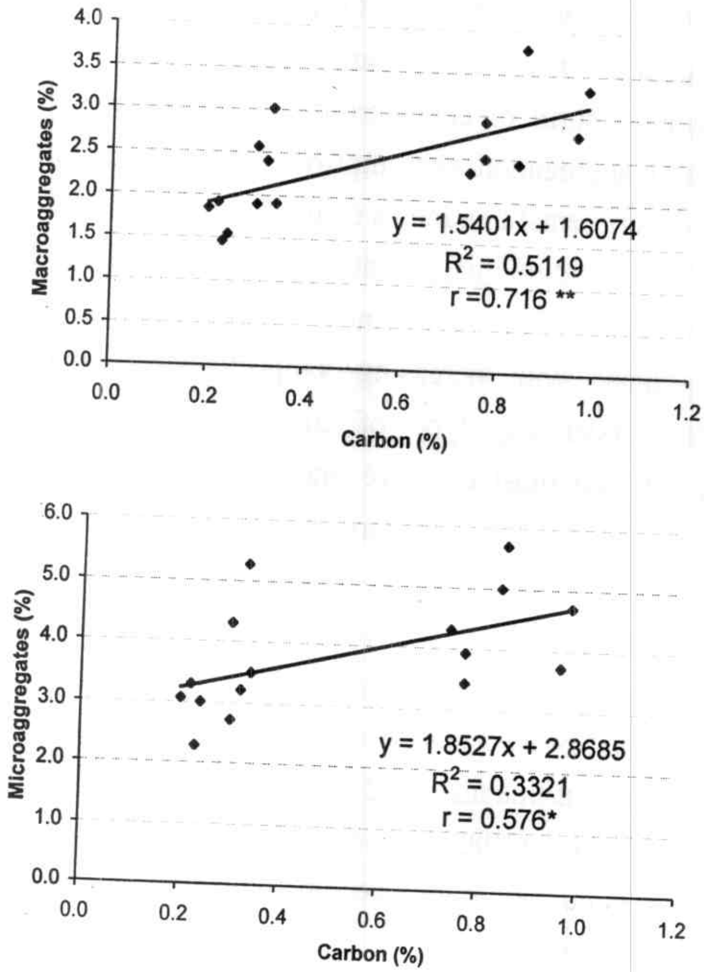
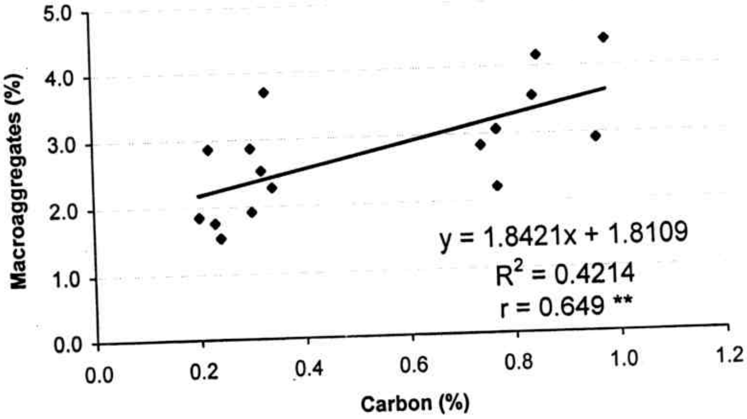


Fig (5): Relation between organic carbon percentages and water stable macro and micro-aggregates percentages of town refuse compost.



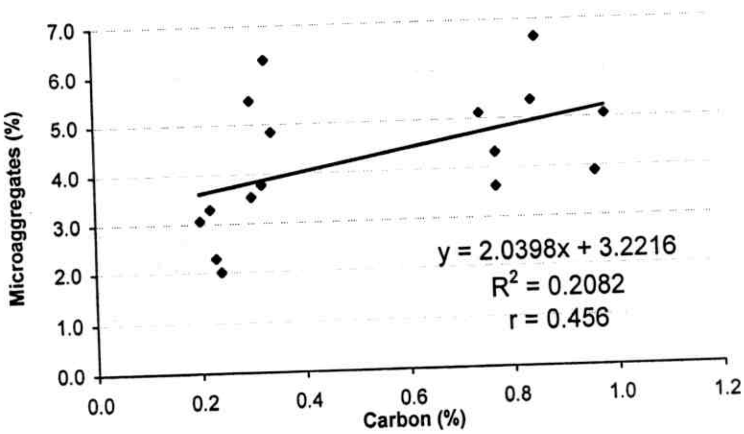
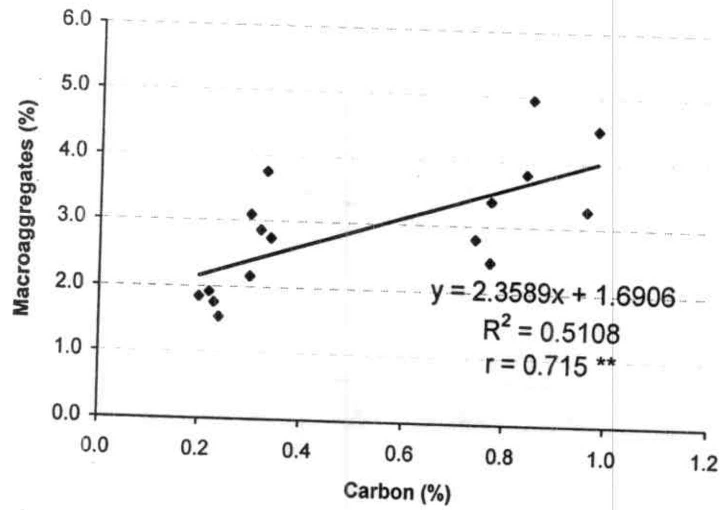


Fig (6): Relation between organic carbon percentages and water stable macro and micro-aggregates percentages of farmyard manure compost.



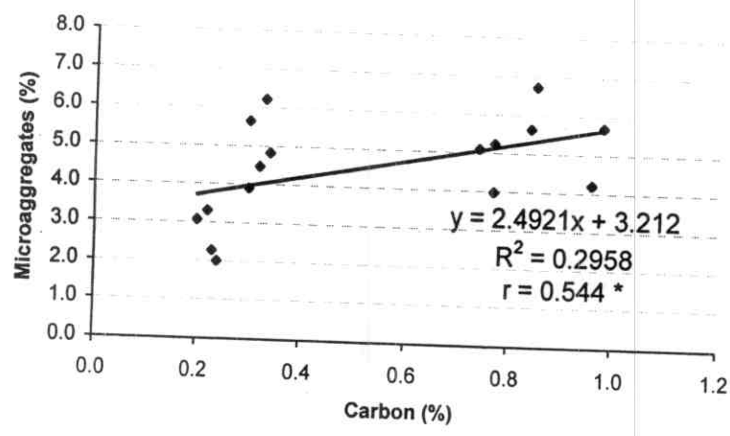


Fig (7): Relation between organic carbon percentages and water stable macro and micro-aggregates percentages of sheep dung compost.

constituents of the formers than the latter, Table (2), can lead to easy mixed and homogenous distribution of organic fractions and by shrink-expand process under short irrigation intervals, the soil aggregates formation will be encouraged. The application of short irrigation interval, (50 % dep.) induced the formation of micro-aggregates than the macro-ones. The same trend was happened under the long irrigation interval but in less magnitude, in their values. These results could be rendered to the differential expansion and shrinkage of calcareous soil particles caused by frequent soil wetting and drying under short or long irrigation intervals which promoted micro-aggregates establishment as first step for macro-water stable aggregate formation. These results were in agreement with those reported by (El-Sersawy, 1989 and El-Maghraby, 1997).

Concerning, the effect of biofertilizer application on soil water stable aggregates the data in Table (11, a and b) pointed out that the addition of some suitable bacterial strains helped the formation of water stable aggregates in soil treatments by great extent as compared with the untreated plots, (without biofertilization). Whereas the increasing percent relative to the control amounted 152 and 132 % pertaining to the former and the latter condition, respectively. So, the increasing effects of bacterial fertilization reached 20 %. These results indicated the essential combination between organic composting and biofertilization for soil structure amelioration in calcareous soil. In the same time, the effect of biofertilization induced the formation of smaller aggregates than the larger ones. The effect of microorganisms on soil aggregation was due to the organic polymer products (e.g. humic acid and fulvic acids) which bind soil particles into micro-aggregates. In addition the microbial cell walls, carbohydrates, polysaccharids and different microbial biomass play an important role in binding the individual soil particles and stabilize those formed aggregates, Tisdale and Oades (1982), Foster *et al.* (1983) and Kladivko (1994).

The statistical analysis, the data in Table (12) indicated that the treatments either with biofertilization or without biofertilization were highly significant effect on forming water stable aggregates in the soil. The separate effects of compost types (T), addition rates (R) and irrigation water depletion (D) were significantly affect water stable aggregate percentages. These results emphasized the suitability of such variables to improve the structure of calcareous soil. The second and the third reactions were concomitant behavior in affecting soil aggregate stability such as individual ones. This means that the interactions between the variables were powerful influence on creating a lot of stable aggregate units in the soil under study.

Table (12): Values of LSD of water stable aggregates as affected by the experimental variables.

Biofertilization	D	T	R	D x T	D x R	T x R	T x D x R
With	0.0474	0.0044	0.0167	0.0044	0.0164	0.0164	0.0164
	*	***	***	***	***	***	***
Without	0.0094	0.0169	0.0203	0.0169	0.0030	0.0030	0.0030
	**	***	***	***	***	***	***

*Sig. 0.05

** Sig. 0.01

***Sig. 0.005

Correlation and regression analyses carried out between organic carbon percent of soil treatments and both stable macro & micro- aggregates of the same soil treatments under different compost types, are illustrated in figs. (5, 6 and7). The results revealed a highly significant correlation between organic carbon percent and stable macro aggregates produced under any types of composts. The correlation coefficients amounted 0.715, 0.649, and 0.716 for sheep dung, farmyard and town refuse composts, respectively.

The corresponding regression equations were as following:

Y= 1.752 X + 1.549, (for sheep dung)

Y= 2.622 X + 1.419, (for farmyard)

Y= 3.089 X +1.375, (for town refuse)

Where (Y) is macro aggregates percent and (X) is organic carbon percent. The same trend was shown in case of microaggregates where the correlation coefficients amounted, 0.576, 0.456, and 0.544, under town refuse, farmyard and sheep dung, respectively.

The regression equations described these relations were as following:

Y= 1.981 X +3.301, (for town refuse)

Y= 2.823 X +3.510, (for farmyard)

Y=3.388 X + 3.332, (for sheep dung)

Where (Y) is the micro aggregates percent, and (X) is the soil organic carbon percent.

It appeared that, application of sheep dung compost was suitable to improve the macro & micro aggregates percentage, than the other organic composts.

4. 1. 4. Soil moisture retention and availability:

The effect of compost types and rates, depletion levels and biofertilization on soil available water of Maryut soil is illustrated in Table (13). The given data showed that all composting types increased the values of soil available water and such increase was more remarkable under sheep dung than other types. The rate of increase reached 31, 23 and 13 % for sheep dung, farmyard and town refuse respectively. It is also evident that such effect increases with increasing application rates. In case of sheep dung, the increase of soil available water amounted 20, 33 and 41 %, upon applying 5, 10 and 15-ton/fed. This effect was rendered to the high ability of retaining water. Table (13) revealed that sheep dung gave the high percent of maximum water holding capacity as compared with other ones.

The corresponding increase in soil available water reached 12, 21 and 33 % of (FYM) and 5, 12 and 21 % for (TR) in the same sequence. Generally, the effect of these, composting types on available water could be arranged in the following order; composted sheep dung > farmyard manure > town refuse.

The data showed that under 15 ton/fed. application rate of sheep dung gave the highest effect on soil available water 41 % comparing the control. The increase of soil available water upon composting could be ascribed to the beneficial effect of such materials on increasing soil aggregation and thereby pore size distribution, especially the small and medium pores. Likewise, humus (which is the product of microbial decomposition of these composting types) can absorb more than six times of its own weight of water thereby increasing the ability of soil to retain water. These

Table (13): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil available water (on weight basis).

Biofertilization	Depletion levels	Control	Value and increase %	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	17.80	Value	19.86	21.97	23.95	21.40	23.70	26.85	23.60	26.50	27.66
			Increase %	11.57	23.43	34.55	20.22	33.15	50.84	32.58	48.88	55.39
	70 %	17.78	Value	18.84	20.39	21.90	20.20	21.65	24.50	21.70	23.10	25.30
			Increase %	5.96	14.68	23.17	13.61	21.77	37.80	22.05	29.92	42.29
Without	50 %	17.58	Value	18.00	19.02	21.60	19.30	21.60	23.00	20.20	24.10	25.85
			Increase %	2.39	8.19	22.87	9.78	22.87	30.83	14.90	37.09	47.04
	70 %	17.50	Value	17.70	18.10	18.80	18.57	18.90	20.00	19.00	20.10	21.08
			Increase %	1.14	3.43	7.43	6.11	8.00	14.29	8.57	14.86	20.46

conclusions stood in agreement with those reported by Anger and Dayegamiye (1991) and Tester (1990).

Concerning the effect of depletion levels, the data indicated 50 % depletion level was greater effect on (A.W.) of soil rather than 70 % depletion one, by 10 %. This may be attributed to the application of short irrigation regime led to increase the ability of the organic materials to form soil aggregates, thereby formation of fine and medium pore sizes which can able to attract water as well as the activity of organic matter surfaces for imbibing water especially under 50 % soil water depletion than the other one. Similar conclusion was reported by (Ahmed 2000).

Regarding the effect of biofertilization on soil available water, data showed that the enhancement in soil (A.W.) took the priority effect on biofertilizer application than without biofertilization, where, the improving percent reached to 13 %. This in fact, is expressed the interaction between organic composting application and bacterial inoculation in increasing the active surfaces of soil which can able to attract irrigation water far of deep percolation. These results are concomitant with those of Kladivko (1994), El-Sersawy (1996) and El-Shakweer et al (1998).

The statistical analysis given in Table (14) emphasized that the individual factors and the interaction between them are highly significant effect on available water. The compost types (T), rates (R) and depletion level (D) either under biofertilization or without biofertilization were effective in improving water availability in the studied soil.

Table (14): Values of LSD of available water as affected by the experimental variables.

Biofertilization	D	T	R	D X T	D X R	T X R	T X D X R
With	0.0186	0.1229	0.0823	0.1229	0.0823	0.0823	0.0823
	***	***	***	**	***	***	***
Without	0.1544	0.1497	0.1168	0.1479	0.1168	0.1168	0.1168
	*	***	***	***	***	***	***

*Sig. 0.05

** Sig. 0.01

***Sig. 0.005

4.1.5. Soil hydraulic conductivity:

The effect of composting types & rates, depletion levels and biofertilization on saturated soil hydraulic conductivity (HC) of Maryut soil illustrated in Table (15). The data showed that application of composting materials increased the values of soil hydraulic conductivity, and such increase reached 158 % upon using farmyard manure, relative to control. Also, sheep dung and town refuse achieved 157 and 81 % increase in saturated HC, respectively. This increase was concomitant with increasing application rates of these composts. In case of FYM the increase in (HC) approached 123, 230 and 280 % upon using 5, 10 and 15-ton/fed., respectively. While it reached 120, 228 and 279 % for (SD) and 63, 89 and 197 % for (TR) upon using 5, 10 and 15-ton/fed., respectively. Generally, the effect of these, composts on hydraulic

Table (15): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on hydraulic conductivity (cm/h).

Biofertilization	Depletion levels	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
			Addition rates (ton/fed.)								
			5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	2.08	2.99	4.40	6.64	4.98	7.61	8.25	4.95	7.47	8.20
		M	M	M	M.R	M	M.R	M.R	M	M.R	M.R
		Increase %	43.75	111.54	219.23	139.42	265.87	296.63	137.98	259.13	294.23
	70 %	2.05	2.90	3.76	6.29	4.56	7.53	8.10	4.51	7.44	8.07
		M	M	M	M.R	M	M.R	M.R	M	M.R	M.R
		Increase %	41.46	83.41	206.83	122.44	267.32	295.12	120.00	262.93	293.66
without	50 %	2.08	2.73	3.94	6.08	4.72	6.10	7.66	4.67	6.12	7.64
		M	M	M	M	M	M	M.R	M	M	M.R
		Increase %	31.25	89.42	192.31	126.92	193.27	268.27	124.52	194.23	267.31
	70 %	2.05	2.64	3.56	5.58	4.17	6.07	7.46	4.12	6.15	7.50
		M	M	M	M	M	M	M.R	M	M	M.R
		Increase %	28.78	73.66	172.20	103.41	196.10	263.90	100.98	200.00	265.85

Hydraulic conductivity class:
M : Moderate.
M R : Moderately rapid.

conductivity could be arranged in the following order, farmyard manure > sheep dung > town refuse. These results may be due to the effect of organic materials on soil structure. These results are in agreement with findings of Gupata *et al.* (1977), Weil and Kroontje (1979), Turner *et al.* (1994) and Kladivko (1994).

Regarding the effect of depletion levels, the data indicated that 50 % depletion level was greater effect on (HC) rather than 70 % depletion one by 5 % only. The short irrigation intervals induced the formation of water stable aggregates, while long one destroyed it. Thereby, increasing micropores led to increase hydraulic conductivity for short irrigation intervals as compared with the other ones. These conclusions stood in agreement with those reported by Aziz et al. (1999), El-Sersawy (1989).

The data also showed that the soil (HC) under biofertilizer technique reached two folds that under unbiofertilization treatment. This might rendered to microbial activity, which may enhance the formation of large soil aggregates thereby increasing hydraulic conductivity under biofertilization. Similar conclusion were reported by Khalil *et al.* (1997), Kowalenko *et al.* (1978) and Abou-El-Naga *et al.* (1982) reported that microbial number and activity in soil are correlated with organic manure content, subsequently play an important role in improving hydraulic conductivity of soil.

The obtained statistical analysis results indicated significant effects of compost types (T) and rates (R), and soil water depletion levels (D) on (HC), table (16). In regard, The data also clarified that the compost rate (R) is the main factor affecting hydraulic conductivity of the soil followed by irrigation water depletion (D) and the compost type (T).

Table (16): Values of LSD of hydraulic conductivity as affected by the experimental variables.

Biofertilization	D	T	R	D X T	D X R	T X R	T X D X R
With	0.0752	0.1823	0.2084	0.3158	0.2947	0.3609	0.5104
	**	***	***	***	ns	ns	***
Without	0.0785	0.2052	0.1542	0.3554	0.2180	0.2667	0.3776
	*	ns	***	Ns	ns	***	ns

*Sig. 0.05

** Sig. 0.01

***Sig. 0.005

The results of correlation and regression analysis clarified that the increase in soil hydraulic conductivity (HC) was more tight correlated with the formation of macro & micro-aggregates under different types of composts. The multiple correlation coefficients between the variables amounted, 0.887, 0.863 and 0.67 % under sheep dung, farmyard and town refuse composts, respectively. The regression equations describing these relations under the condition of three organic composts were as following:

HC= - 3.151+ 1.916 macroaggr.+ 0.498 microaggr. (Sheep dung).

HC = - 0.740 + 3.060 macroaggr. + 0.495 microaggr, (Farmyard).

HC= - 2.125 + 0.353 macroaggr.+ 1.250 microagg , (Town refuse).

These equations pointed out that hydraulic conductivity (HC) was the function of stable macro aggregates formation under sheep dung and farmyard composts while, it was functioned of stable micro-aggregates formation in case of town refuse one.

Concerning the relation between hydraulic conductivity (HC) and pore size distribution, the equations, which described it under different organic composts, were illustrated as following:

HC= -36.005+0.385 large pores +0.896 medium pores +1.231 small pores.

HC= -13.666-0.067 large pores +1.331 medium pores + 0.473 small pores

HC= -2.096 – 0.182 large pores + 1.269 medium pores + 0.175 small pores

These treatments were under town refuse, farmyard and sheep dung, respectively. The different coefficients in the three equations showed that treated calcareous soil with town refuse caused a positive effect on (HC) which was more correlated with large medium and small pores formation. While, treating the soil with sheep dung and farmyard led to positive effect on (HC) but it was more responded with medium and small pores only.

4. 1. 6. Soil mechanical properties:

a. Soil penetration resistance:

The data given in Table (17) reveal the effect of the types and rates of composts, irrigation regimes and biofertilizers on soil penetration resistance of soil at (0-10), (10-20) and (20-30)-cm depths. The data show general reduction in soil resistance upon applying compost. This reduction occurs in the studied soil depths but with varying degrees. Town refuse compost reduced the soil penetration resistance by, 21, 18 and 17 % for the first, second and third depth (as mean values), respectively. The same trend was

Table (17): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil penetration resistance (kg/cm^2).

Biofertilization	Depletion levels	Depth (cm)	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	0-10	53.94	40.75	37.33	35.33	45.00	38.46	35.67	47.00	42.00	37.67
		10-20	61.80	56.42	52.00	46.54	56.00	45.00	42.33	52.58	48.58	44.42
		20-30	66.11	60.42	55.42	49.00	58.54	54.50	48.00	54.50	50.67	47.00
	70 %	0-10	58.10	49.75	48.00	42.83	45.25	43.25	40.00	46.33	43.17	40.00
		10-20	59.50	50.67	47.17	40.67	51.17	45.21	41.25	53.75	46.33	42.29
		20-30	68.14	61.33	55.00	49.00	61.83	58.25	52.42	62.57	49.00	54.00
Without	50 %	0-10	54.75	48.08	39.50	38.00	50.47	44.33	39.25	49.00	45.83	40.33
		10-20	62.15	57.00	51.75	43.42	52.25	48.32	44.58	59.58	49.50	45.08
		20-30	69.40	59.83	57.83	56.00	59.58	58.00	53.17	64.00	60.80	56.58
	70 %	0-10	58.91	54.38	51.88	49.00	47.17	45.25	43.00	49.67	47.25	42.50
		10-20	62.47	58.13	54.42	46.04	59.33	56.58	52.28	.55.92	47.21	43.88
		20-30	69.00	62.13	57.33	54.33	60.25	56.00	52.00	63.33	60.00	55.79

achieved upon using farmyard or sheep dung composts. The decline percent associated with such two compost types amounted 24, 21 and 18 % and 22, 20 and 16 % for the three depths of the sheep dung and farmyard, respectively. The relative decrease in penetration resistance in the lower depth can be attributed to the relative high content of organic matter and to higher microbiological activity and growth in such depth. Bradford (1986) reported that penetration resistance increased with depth and it approached a maximum at certain critical depth.

It is also evident that the rate of decrease in penetration resistance was correlated to application rates of the composts in any soil depth. The decreasing percent of soil resistance in soil depth of (0-10 cm) reached to 15, 22 and 28 % (mean value) as application rate increased gradually from 5 to 10 to 15 ton/fed., irrespective to the type of compost. The second depth (10-20 cm) produced less resistance reduction where it amounted 10, 20 and 26 % under gradually change in application rates. This reduction was more less in the third depth (20-30 cm) by percent of 10, 16 and 23 %. From these results it could be concluded that with increasing compost rate 5 ton/fed., the soil penetration resistance reduced as 8 %. In addition, it was found that every one ton/fed. composting additive led to a decrease in soil penetration resistance equal 1.4, 1.2 and 1.1 kg/cm^2, associated with upper, middle and lower soil depth, respectively. This reduction in penetration resistance accompanied with organic compost treatments is attributed to the supporting effects of various organic products as binding agents for individual soil particles forming stable soil aggregates with good porosity condition for root growth and distribution, thereby soil resistance minimized as compared with uncomposted treatment. These results are concomitant with those reported by Soane (1990) and Quiroga *et al.* (1999) whose observed inversely relation between resistance to penetration and soil organic matter content. They added that soil organic matter reduced the susceptibility to compaction and mechanical impedance of compacted soils subsequently enhancing the plant root growth.

The effect of irrigation regime as the application of 50 or 70 % depletion level on penetration resistance was shown in Table (17). The data revealed that the interaction between composting addition and irrigation water frequency along the growth season caused a great reduction in penetration resistance of the three soil depths. The decrease percent amounted 16, 18 and 19 % under the irrigation regime of 50 % depletion while it amounted 18, 19 and 26 % under the other one of 70 % depletion level. This trend could be rendered to the co-operative effect of organic composts and wetting and drying cycles of irrigation water in reducing mechanical strength and compaction of calcareous soil. These results are in agreement with those of Lund *et al.* (1975), Soane (1990) and El-Sersawy (1997). They concluded that incorporation of composted sheep dung, farmyard manure and garbage were able to overcome compaction and recover structure of soil through repeated wetting–drying cycles. It is interested that the effect of compost treatments on increasing soil moisture retainability reflected on soil penetration resistance values in the three studied depths. Whereas, in Table (18) and Figs (8, 9 and 10) the increase in soil moisture content of the treatments accompanied the decrease in soil resistance values.

Table (18): Moisture content percent of soil treatments during penetration resistance estimation for three depths (0 - 10, 10 - 20 and 20 - 30 cm).

Biofertilization	Depletion levels	Depth (cm)	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	0-10	9.51	9.80	10.34	10.50	10.47	10.82	11.40	10.90	11.70	12.02
		10-20	9.88	10.42	11.85	11.94	11.99	12.40	12.85	12.70	12.92	13.78
		20-30	10.34	11.31	12.25	12.48	12.80	12.98	13.20	13.20	13.70	14.95
	70 %	0-10	9.50	9.74	10.30	10.42	10.40	10.75	11.31	10.83	11.64	12.00
		10-20	9.86	10.36	11.81	11.90	11.95	12.20	12.77	12.64	12.85	13.73
		20-30	10.30	11.27	12.21	12.44	12.71	12.92	13.10	13.05	13.62	14.87
Without	50 %	0-10	9.50	9.75	10.30	10.45	10.42	10.71	11.31	10.84	11.67	12.00
		10-20	9.86	10.37	11.81	11.90	11.86	12.33	12.77	12.67	12.85	13.71
		20-30	10.31	11.25	12.17	12.41	12.73	12.92	13.07	13.12	13.66	14.84
	70 %	0-10	9.49	9.73	10.28	10.41	10.40	10.68	11.27	10.80	11.62	11.97
		10-20	9.84	10.34	11.76	11.86	11.91	12.16	12.74	12.60	12.81	13.70
		20-30	10.27	11.22	12.08	12.37	12.68	12.86	13.00	13.02	13.60	14.81

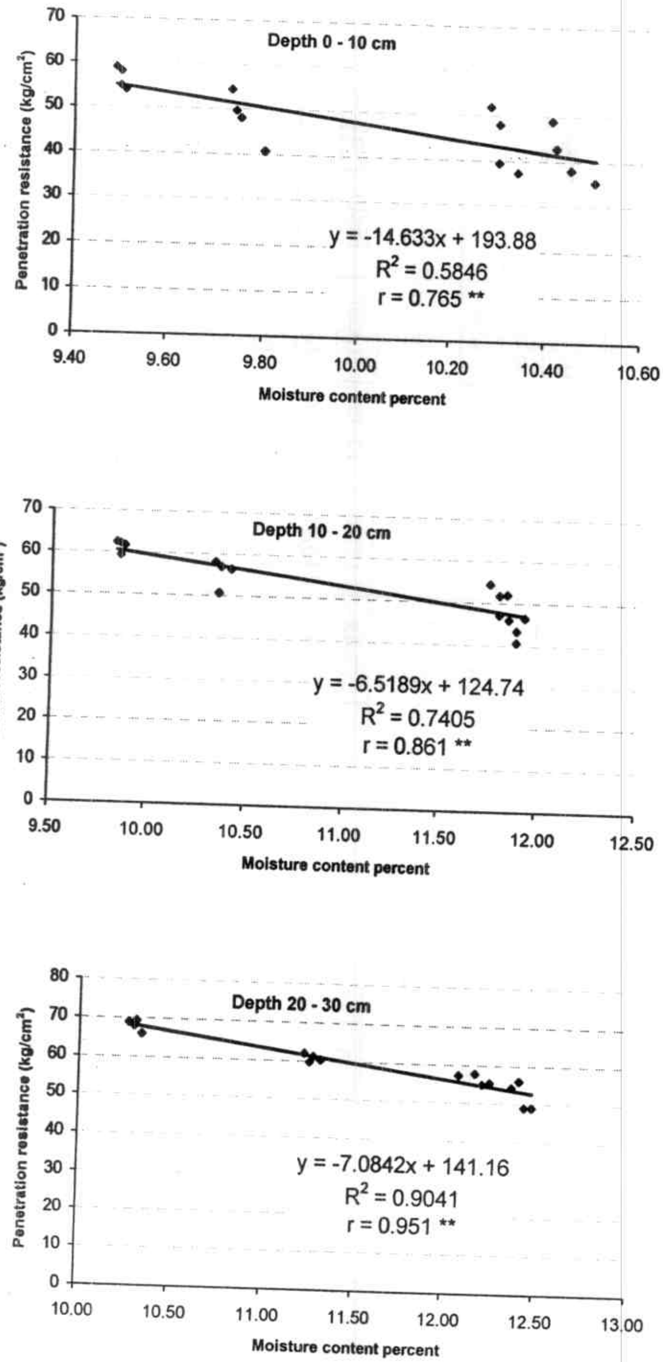


Fig. (8): The combined effect between soil moisture content and penetration resistance of three depths (0 -10, 10 - 20 and 20 - 30 cm) under the effect of town refuse compost treatment.

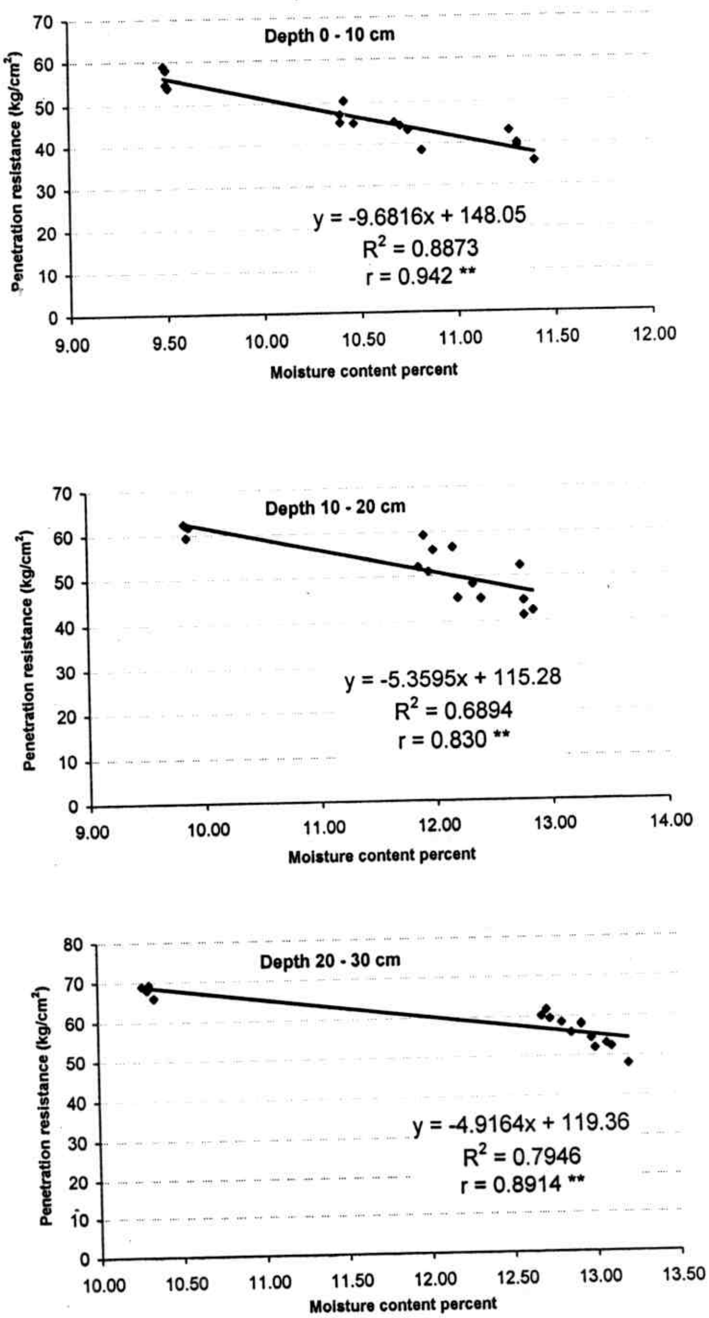


Fig. (9): The combined effect between soil moisture content and penetration resistance of three depths (0 -10, 10 - 20 and 20 - 30 cm) under the effect of farmyard manure compost treatment.

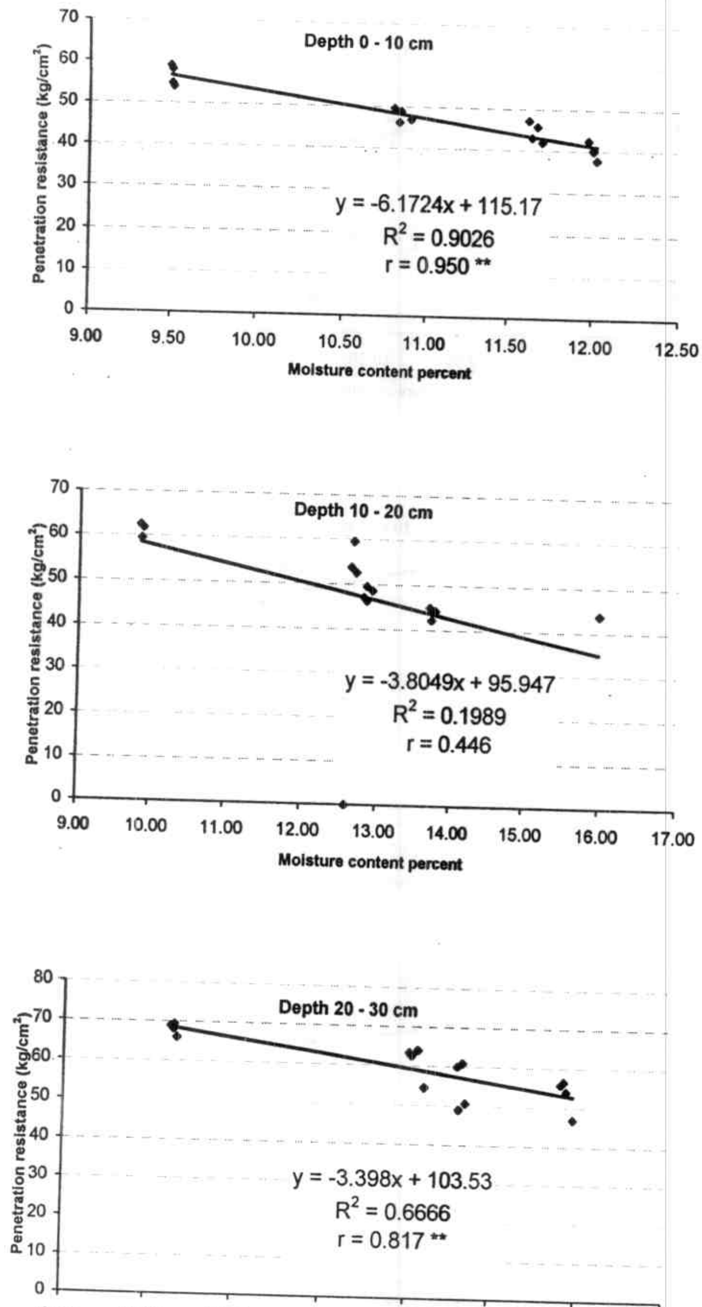


Fig. (10): The combined effect between soil moisture content and penetration resistance of three depths, (0 -10, 10 - 20 and 20 - 30 cm) under the effect of sheep dung compost treatment.

The data in the same table substantiated the essential effect of biofertilizer technique especially, with soil composting incorporation to minimize penetration resistance of soil. The reduction percent reached to 25, 22 and 19 % in soil resistance to penetration for first, second and third depths, respectively under the condition of biofertilizer applications. While, under the condition of soil composted treatments but, without biofertilization process, the reduction percent amounted 19, 16 and 15 % for the three soil depths, respectively. This clarified the importance of biofertilization as it affected by about mean value of 6 % within the effect of all factors, which help in reducing soil mechanical strength. These data go hand in hand with those of El-Sersawy *et al.* (1996) and Abd El-Ghany *et al.* (1997).

The statistical analyses given in Table (19) emphasized the effect of type (T) and rate (R) of composts, depletion level (D) on penetration resistance was significant. The data also clarified that the depletion level (D) was the most important factor affecting of soil penetration resistance followed by the type of compost (T) and application rate (R).

The relation between penetration resistance in every soil depth and the corresponding values of soil bulk density was illustrated in Figs (11,12 and 13). It is evident that the application of sheep dung, farmyard and town refuse composts reduced soil penetration resistance. The obtained regression equations relating the values of penetration resistance at 0-10, 10-20 and 20-30 cm depths (Y) and the values of bulk density (X) under different compost types, were as follows;

Y= 107.61X - 98,687, (sheep dung 0-10 cm depth).

Y= 99.311 X - 90.991, (sheep dung 10-20 cm depth).

Table (19): Values of LSD of soil penetration resistance as affected by the experimental variables.

Biofertilization	Depth (cm)	D	T	R	D X T	D X R	T X R	T X D X R
With	0 - 10	0.1483 ***	1.0258 ns	0.6434 ***	1.0258 ***	0.6434 *	0.6434 ***	0.6434 ***
	10 - 20	0.0931 ***	0.8653 **	0.9444 ***	0.8653 ***	0.9444 ns	0.9444 ***	0.9444 ***
	20 - 30	0.3012 **	0.8426 ***	0.7286 ***	0.8426 ***	0.7287 ***	0.7287 **	0.7287 ***
Without	0 - 10	1.3326 **	0.3177 ***	0.8085 ***	0.3177 ***	0.8085 ***	0.8085 ***	0.8085 ***
	10 - 20	0.1079 **	0.6778 ***	0.9451 ***	0.6779 ***	0.9451 ***	0.9451 ***	0.9451 ***
	20 - 30	1.4257 *	0.9582 ns	0.5683 ***	0.9582 ***	0.5683 ***	0.5683 ***	0.5683 ***

Where:
N = 144
D = depletion level.
T = compost type.
R = compost rate.

*Sig. 0.05 ** Sig. 0.01 ***Sig. 0.005
D x T = interaction between depletion and compost type.
D x R = interaction between depletion and compost rate.
T x R = interaction between both compost type and rate.
T x D x R = interaction between the three variabls, i.e; compost type, depletion level and compost rate.

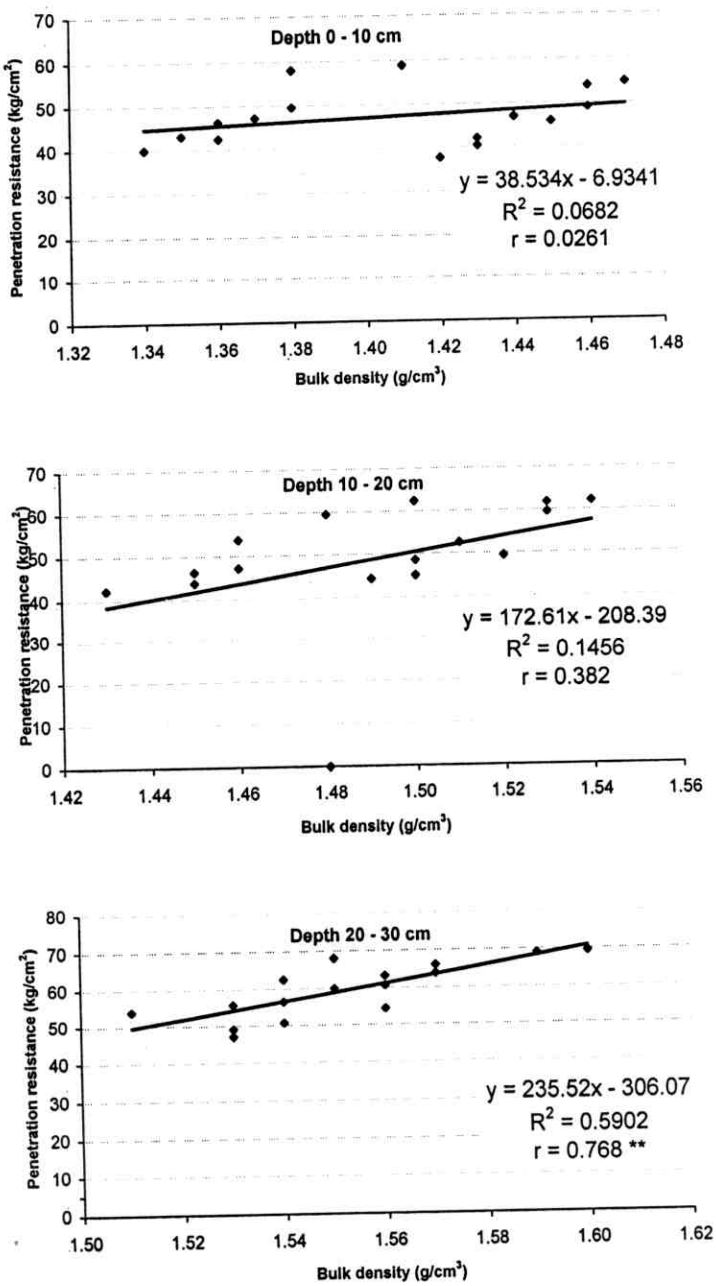


Fig. (11): The combined effect between soil bulk density and penetration resistance of three depths, (0 -10, 10 - 20 and 20 - 30 cm) under the effect of town refuse compost treatment

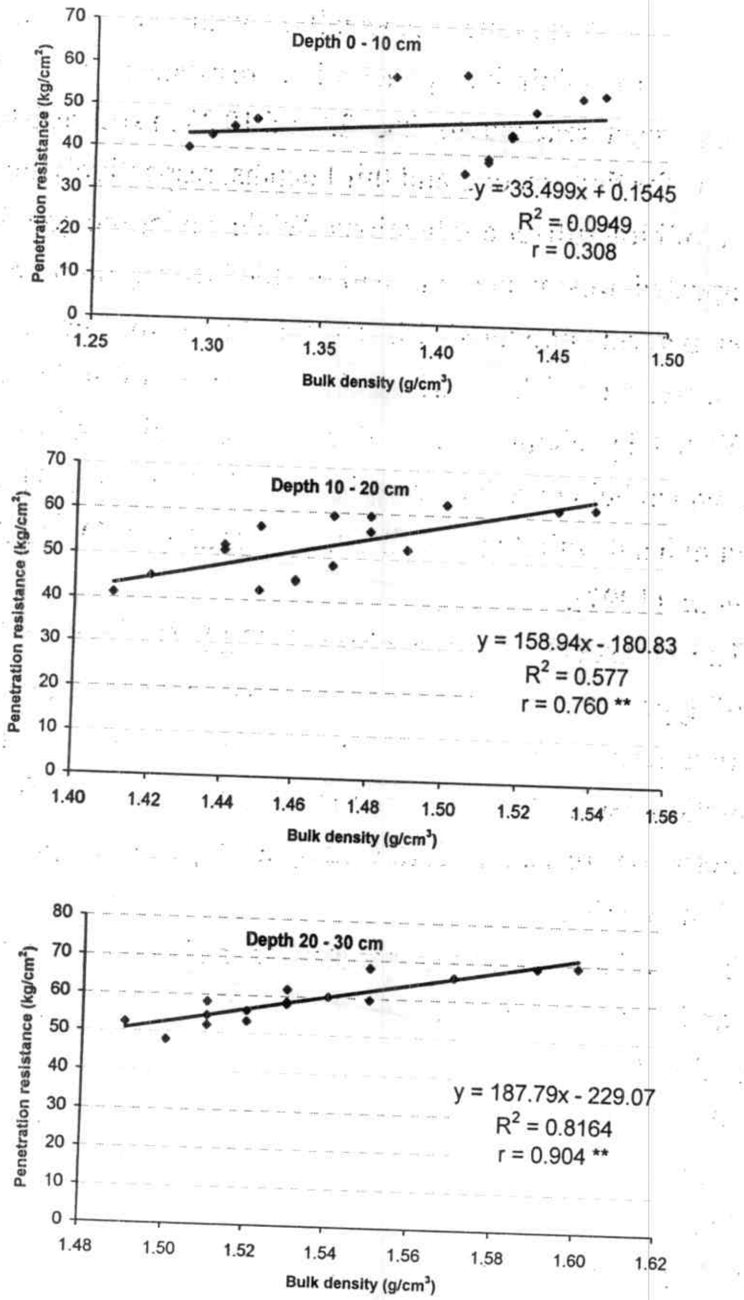
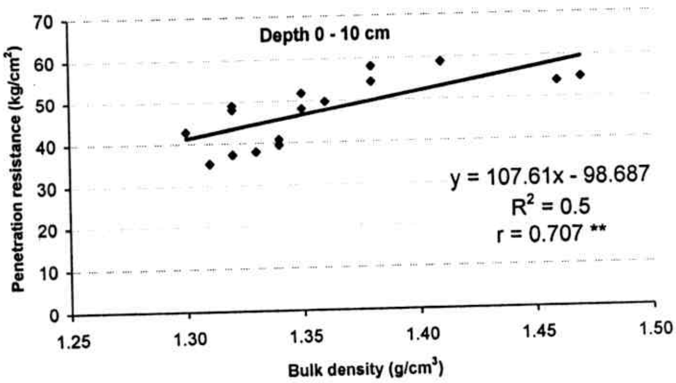
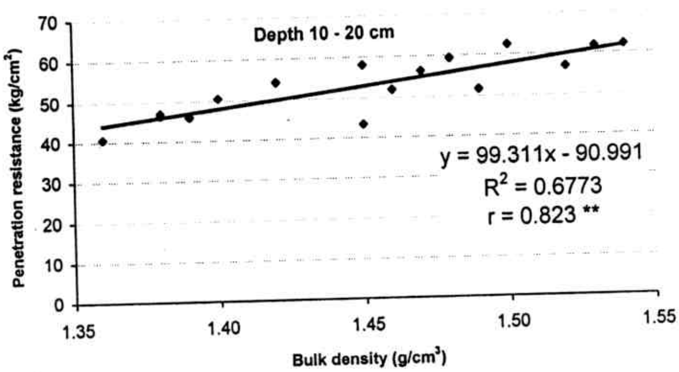


Fig. (12): The combined effect between soil bulk density and penetration resistance of three depths, (0 -10, 10 - 20 and 20 - 30 cm) under the effect of farmyard manure compost treatment.





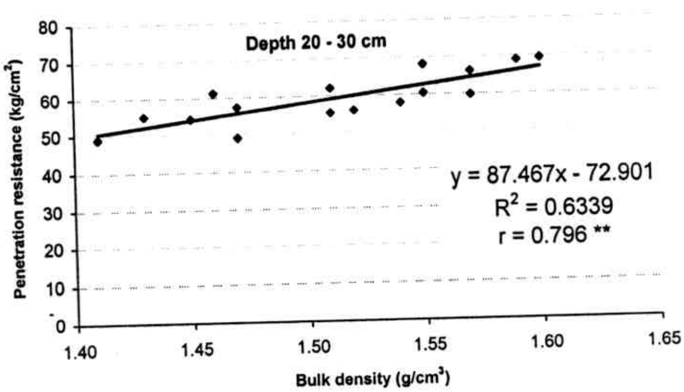


Fig. (13): The combined effect between soil bulk density and penetration resistance of three depths, (0 -10, 10 - 20 and 20 - 30 cm) under the effect of sheep dung compost treatment.

Y= 87.467 X - 72.901, (sheep dung 20-30 cm depth).
Y= 33.499 X - 0.155, (farmyard 0-10 cm depth).
Y= 158.94 X - 180.83, (farmyard 10-20 cm depth).
Y= 187.79 X - 229.07, (farmyard 20-30 cm depth).
Y= 38.534 X - 6.934, (town refuse 0-10 cm depth).
Y= 172.610 X- 208.39, (town refuse 10-20 cm depth).
Y= 235.52 X - 306.07, (town refuse 20-30 cm depth).

These equations took linear relations between bulk density and penetration resistance of soil treatments. It means that by increasing soil bulk density, the soil resistance to penetration increases and vice versa. Thus, it could be concluded that the improvement of structural soil properties of calcareous soil such as aggregation, porosity and bulk density, due to organic additives, suitable irrigation regime, and biofertilization application, reflected on desirable soil mechanical properties, such as penetration resistance.

b. Soil shear strength:

The data shown in Table (20) reveal the influence of composting types, application rates, irrigation regime and biofertilization on soil shear strength and its other related aspects, i. e., cohesion forces and internal friction angle. The data indicated that using composts minimizes the values of shear strength. However, such trend varied according to the compost type, and its rate of application. It is evident that sheep dung achieved the higher reduction than farmyard and town refuse. Where the average reduction values amounted 23, 20 and 19 %, respectively. This behavior could be attributed to the effectiveness of sheep dung in

Table (20): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil shear strength (kg/cm²).

Depletion levels	Compost treatments	(ton/fed.)	With biofertilization			Without biofertilization		
			S	C	Φ^o	S	C	Φ^o
50 %	Town refuse (TR)	0.0	81.48	10.99	46.00	83.38	11.34	47.00
		5.0	63.67	6.82	35.00	65.59	7.88	39.63
		10.0	59.26	5.70	33.00	60.54	6.47	37.00
		15.0	54.38	4.80	31.00	59.03	5.57	36.00
	Farmyard manure (FYM)	0.0	81.46	10.99	46.00	83.86	11.34	47.00
		5.0	68.63	7.81	38.00	72.08	8.80	40.00
		10.0	61.83	6.77	34.00	67.42	7.66	38.00
		15.0	58.54	5.83	33.00	65.58	6.65	37.00
	Sheep dung (SD)	0.0	81.48	10.99	46.00	83.36	11.34	47.00
		5.0	66.67	8.37	39.00	68.08	9.15	42.00
		10.0	61.79	6.75	35.00	64.74	7.35	39.00
		15.0	59.71	5.74	31.00	61.21	6.53	33.00
70 %	Town refuse (TR)	0.0	92.24	9.19	42.84	90.73	10.27	45.00
		5.0	77.38	7.07	37.27	84.00	7.50	39.37
		10.0	75.58	6.34	35.00	78.25	6.59	38.00
		15.0	70.75	5.18	32.00	75.00	5.70	37.00
	Farmyard manure (FYM)	0.0	92.24	9.19	43.00	90.71	10.27	45.00
		5.0	79.42	6.87	39.00	82.20	7.58	39.00
		10.0	73.58	6.26	37.00	79.24	6.92	38.00
		15.0	66.64	5.00	34.00	68.64	5.48	36.00
	Sheep dung (SD)	0.0	92.24	9.19	43.00	90.71	10.27	45.00
		5.0	72.92	5.94	39.00	78.24	8.18	40.65
		10.0	68.58	5.02	38.00	72.12	7.72	35.00
		15.0	63.67	4.13	34.00	65.58	6.88	31.00

S : Shear strength (kg/cm²)
C : Cohesion force (kg/cm²)
Φ^o: Internal friction angle (degree)

formation water stable aggregate (53 %) compared to the farmyard (43 %) and town refuse (30 %). This in turn, led to improvement of soil structure and hence reduce the shear forces. These findings matched with those obtained by Soane (1990) and El-Sersawy (1997) and Bazzoffi *et al.* (1998). The application rate of composts tended to go in gradual shear strength reduction as its quantity raised. The reduction percent amounted 15, 21, and 26 % at application rates of 5, 10 and 15 tons/fed., irrespective to compost types.

This mean that by every increase as 5 ton/fed., of compost used, the reduction in shear strength of the soil achieved (5.5 %) comparing with the control, which corresponded (4.66 kg/cm^2) as absolute value of soil shear strength. Thus the addition of one unit of compost (1 ton/fed.) can able to minimize approximately (0.93 kg/cm^2) of soil shear strength, more or less depending on the type of compost. These results are concomitant with those given by Ohu *et al.* (1985), Bazzoffi *et al.* (1998) and El-Sersawy (1998).

The impact of irrigation regime on reducing shear strength shown in Table (20) point out that the short irrigation regime intervals i. e. at 50 % depletion was superior than the long irrigation intervals i. e. at 70 % depletion. The reduction percent amounted 27 and 15 %, for the two applied regimes, which correspond to achieved (-21 %), i.e., (-9.32 kg/cm^2), respectively. Most probably this tendency of reducing shear strength under the short irrigation intervals could be attributed to the effect of frequent wetting and drying cycles which induce soil friability and compaction loosen. This result is in agreement with Soane (1990) Obi and Ebo (1995) and El-Sersawy (1998). As to, the effect of biofertilization on shear strength it is clear that such treatment induced shear strength reduction compared to the control by 5 %. In this accord the bacterial inoculation and foliar application help the organic constituents of composts to decay and produce beneficial compounds that bind soil separates into aggregates, thereby soil mechanical strength reduced, Marshall and Holmes, (1979), Schjonning *et al.* (1994) and El-Sersawy (1997).

According to Mohr-coulomb theory, the shear strength of soil is affected by the, cohesion and inter-granular friction of soil particles, i.e., internal friction angle, (Baver *et al.*, 1976 and Witney, 1988). So the values of cohesion force (C) and internal friction angle (Φ) as affected by organic composting at different rates, irrigation regime and biofertilization were illustrated in Table (20). As regard to cohesion force (C) the data clarify that organic composting technique plays an important role in reducing the cohesion forces between soil particles. The great reduction in (C) values ranged between 36 and 40 % (mean values) decrease relative to the control. These results matched with those of Zhang and Hartge (1995) and El-Sersawy (1997), who reported that organic additives during soil tillage lead to reduce cohesion. The effect of composting application rates on (C) values seemed to be concomitant with the increasing compost quantity from 5 to 10 and to 15 tons/fed. as the reduction percent of (C) values, amounted 27, 37 and 47 % relative to the control.

The magnitude of decrease in (C) values according to every 5 tons/fed., from any organic compost used was corresponded with 10 % reduction , which equal to 1.03 kg/cm^2 cohesion force (C) decrease. This means that under the conditions of this study each 1 ton/fed. from organic composts minimizes 0.21 kg/cm^2 of cohesion force. This trend was in agreement with the findings of Schjonning *et al.* (1994) and El-Sersawy (1998).

In regard to the effect of irrigation regime on cohesion (C) values the data indicated that the application of short irrigation interval (50 % depletion) or long irrigation one (70 % depletion) interacted with composted soil was able to reduce the attraction forces between soil particles which the reduction reached to 40 and 34 % pertaining to the former and latter ones, respectively against the control. This in fact, clarifies the importance of applying irrigation regime at suitable depletion level which verify good soil moisture content for plant growth, and faraway of undesirable irrigation water excess leading to sealing and blocking soil pores. Through the wetting and drying cycles of irrigation water frequencies and in the presence of organic components and plant root penetration, the compaction forces diminished and granular condition of soil created. Baver *et al.* (1976) and Russell (1989) stated that the organic matter constituents that affect physicochemical reactions in the soil are capable to penetrate and hydrate between soil particles under the diffuse double layer system that determine the magnitude of the cohesive components. These components through air-water menisci system affect the distance between particles and the attractive forces of them. In the same direction, the impact of biofertilization on soil cohesion force (C) was to be reduced this force as biofertilizer applied on the soil basically treated with different compost types and rates. The biofertilized treatments achieved 42 % reduction in cohesion force (C) greater than the unbiofertilizated ones, which led to 32 % decrease as compared with control. Thus the effect of soil inoculation and foliar application with suitable bacterial strains help by 10 % in decreasing (C) values. This trend validate the necessity of composting additions in combination with active bacterial groups to overcome the impedance forces in soil. These results are in accordance with the finding of El-Sersawy (1997) and Bazzoffi *et al.* (1998).

Concerning the inter-granular friction of soil particles, or internal friction angle (Φ) as influenced by experimental treatments, the data in Table (20) showed similar trend like the aforementioned one, i.e., cohesion (C). The data display that the reduction rate in (Φ) amounted -21, -18 and -20 % for town refuse, farmyard and sheep dung, respectively and such trend increase with increasing the compost application rate. This decrease amounted 14, 20 and 26 % at 5, 10 and 15 tons/fed., respectively. It could be deduced that every 5 tons/fed., application rate mixed in soil induced 6 % reduction in the angle (Φ) comparative with the control. This reduction corresponded to absolute value of the angle equal 2.62 degree . So, one ton per feddan compost addition leads to decrease in friction angle (Φ) equal 0.52 degree. These findings are matched with those of Bowles (1986) who stated that, in a dense soil (compacted) the friction angle (Φ) ranged between (42 to 45°), while in a loose soil (friable) this angle ranged between (30 to 35°).

In addition the data revealed that the irrigation regime either irrigation frequency at 50 or 70 % depletion from soil available water reduced the angle (Φ) as 20 and 19 %, respectively. This reduction in internal friction angle was due to organic compost additions and the frequent irrigation along the growth season, which led to minimize the cohesion and maximize the adhesion forces, thereby, friction angle between soil particles reduced. Concurrently, the effect of biofertilization on friction angle (Φ) took the same trend of decreasing its values in the biofertilized treatments, (22 %) than the unbiofertilized ones, (17 %). In fact the co-operative effect of compost addition and biofertilization enhances the humates production, bacterial slimes, gums generation and root exudates which act as cohesive substances for soil separates forming soil aggregates with low cohesion (C) and inter-granular friction (Φ) between them. These results are in accordance with those reported by Witney (1988), Russell (1989) and El-Sersawy *et al.* (1993).

The statistical analysis given in Table (21) emphasized the significance of the experimental treatments on soil shear strength. The results indicated the highly significance for compost rates (R) and irrigation water depletion, while it was quietly significant one pertaining the effect of type compost (T). In concerning the second and third interactions the data indicated the necessity and significant of the irrigation water depletion (D) with increasing type of compost (T) and rates (R). Whereas, the data clarified that the compost type (T) and the rate (R) are important factors affecting soil shear strength by irrigation water depletion (D) come after that expressing on the less factor in affecting soil shear strength.

Table (21): Values of LSD of shear strength as affected by the experimental variables.

Biofertilization	D	T	R	D X T	D X R	T X R	T X D X R
With	3.3643	4.5331	2.7112	4.5331	2.7112	2.7112	2.7112
	**	*	***	**	Ns	*	**
Without	3.4618	7.1306	2.9234	7.1306	2.9240	2.9240	2.9240
	**	*	***	**	***	**	***

*Sig. 0.05
** Sig. 0.01
***Sig. 0.005

The relations illustrated in Fig. (14) revealed the correlation and regression analyses between shear strength values and the corresponding of bulk density of soil treatments. The correlation coefficients exhibited good combined significant relations between the two soil favorable items, which (r) amounted 0.725, 0.803 and 0.632, under sheep dung, farmyard and town refuse composts, respectively. The deduced regression equations under each type of compost were as following:

Y= 168.43 X - 155.590, (sheep dung).

Y= 124.12 X - 96.868, (farmyard).

Y= 147.21 X- 134.54, (town refuse).

Where (Y) is the shear strength and (X) is the bulk density. So, the organic treatments, which reduced the bulk density, will be reduced, in the same direction, soil shear strength and vice-versa. Thus, from the practical point of view, the strategy of calcareous soil management should depend upon the organic application to reduce the compactness of soil and thus workability of agricultural machinery.

4.1.7. Soil Erodibility:

Soil Erodibility is defined as the ability of soil to resist the destructive impact or erosion factors. Zachar (1982) and Dimoyiannis *et al.* (1998) reported that the susceptibility of soils to resist erosion is usually called soil Erodibility. In this regard, the size distribution of soil aggregates is important because it determines their susceptibility to movement by wind and water. As regard to wind erosion, Chepil (1958) stated that soil particles of 1.0 to 0.5-mm diameter are difficult eroded, grains of 0.5 to 0.15-mm less erodible and grains of 0.15 to 0.1-mm are most easily erodible ones. The data in Table (22) and Figs.

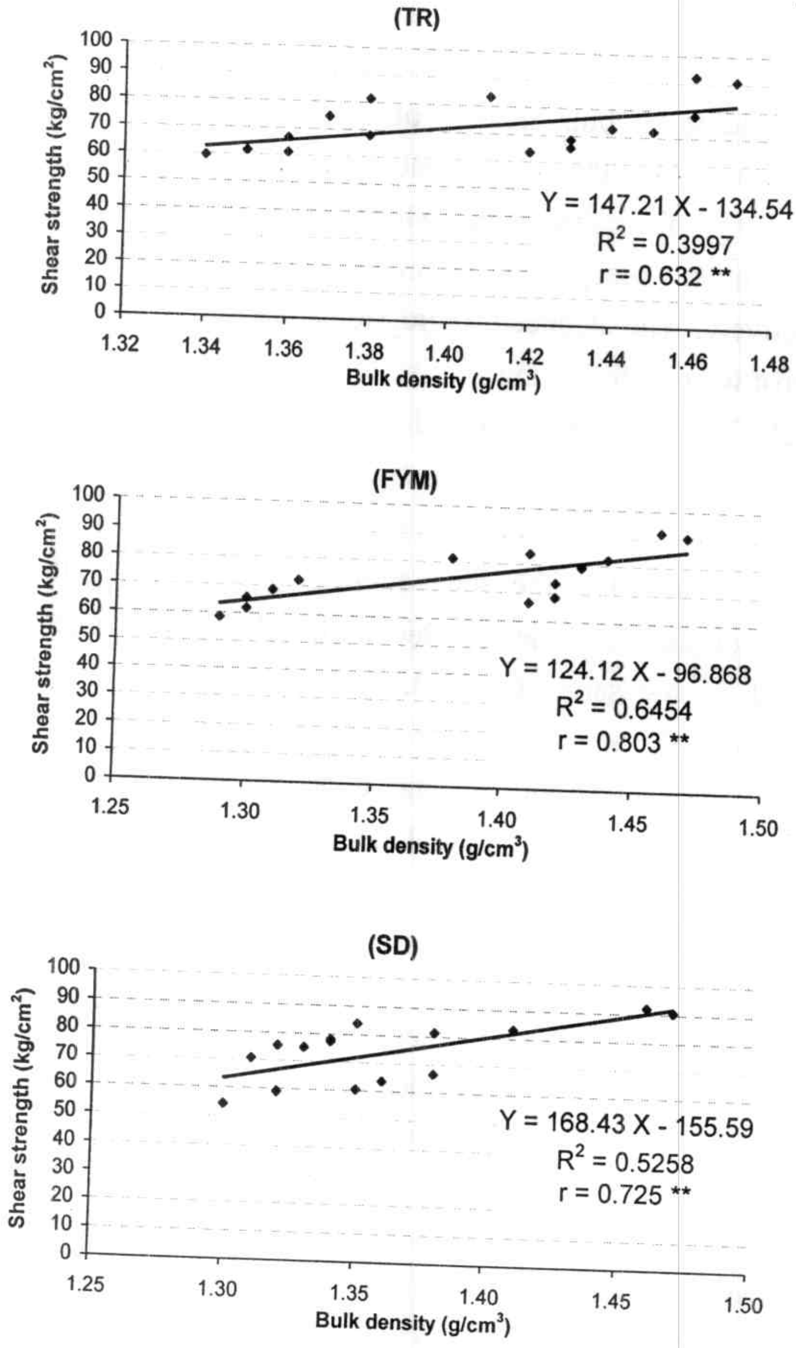


Fig.(14): Relationship between soil bulk density and shear strength of soil town refuse, farmyard and sheep dung compost treatments.

(15, 16, 17 and 18) reveal the effect of organic composts, irrigation regimes and biofertilization treatments on dry stable aggregates as indication to erosion soil resistance. The data clarified a remarkable positive effect of compost types on increasing both the difficult and less erodible grains and less erodible ones but they have negative effects on the easily erodible one.

The farmyard compost treatment surpassed the sheep dung and town refuse composts in this regard. The increasing percent in difficult and less erodible fractions relative to the control amounted 8, 7 and 6 % and 11, 10 and 9 % pertaining to the three organic composts, respectively. This trend could be attributed to the high organic matter content, nutrient concentration and narrow C: N ratio of the two former composts than town refuse one. This in turn, induce high microorganism activity and root branching which help in promoting soil granulation, subsequently increase soil resistance to erosion. These results are concomitant with those reported by Stevenson (1994) and Nearing *et al.* (1990), as they stated that humus increases the ability of the soil to resist erosion due to the formation of soil aggregates and its ability to hold more water. Otherwise the compost type treatments led to decrease in easily erodible fraction as compared with control, as the average reduction reached 14, 8 and 7 % upon using farmyard, sheep and town refuse, respectively. Concerning to the compost application rates, the data cleared that increasing such rates from 5 to 10 to 15 tons/fed., resulted in increasing difficult and less erodible soil fractions and decrease the easily erodible ones. This behavior progressively increased with increasing the application rates. These results point out the important role of organic compost in conserving soil surface from wind erosion action. Hassett and Banwart (1992) reported that the productive top-soil of the agricultural lands must be maintained and protected from erosion upon applying organic matter.

Table (22): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on soil erodibility.

Biofertilization	Depletion levels	Erodibility class	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	50 %	Difficult eroded	41.17	41.76	43.54	43.96	41.85	43.90	44.43	41.78	42.82	44.00
		Less eroded	11.92	12.43	13.52	14.10	12.67	14.08	14.80	12.92	13.68	14.74
		Easy eroded	46.91	45.81	42.94	41.94	45.47	42.02	40.78	45.30	43.50	41.26
	70 %	Difficult eroded	38.79	39.26	41.97	43.12	40.82	43.23	44.22	39.96	42.75	43.02
		Less eroded	11.81	12.75	14.04	14.32	13.09	13.73	14.39	12.90	13.17	13.97
		Easy eroded	49.40	47.98	43.99	42.56	46.09	43.05	41.38	47.14	44.08	43.02
Without	50 %	Difficult eroded	40.75	40.93	42.29	43.25	42.12	43.38	44.12	41.87	43.04	43.33
		Less eroded	11.84	11.97	12.59	12.89	12.19	12.49	13.60	11.74	12.12	13.84
		Easy eroded	47.41	47.10	45.12	43.86	45.69	44.12	42.28	46.40	44.84	42.82
	70 %	Difficult eroded	34.58	35.45	39.54	41.87	36.49	40.48	42.64	35.70	40.79	42.85
		Less eroded	11.73	11.88	12.57	12.96	11.92	12.37	13.73	11.44	11.98	13.01
		Easy eroded	53.70	52.67	47.88	45.18	51.59	47.15	43.64	52.86	47.23	44.14

Difficult eroded: 1.0-0.5 mm.
Less eroded: 0.5- 0.15 mm.
Easy eroded: 0.15-0.1 mm.

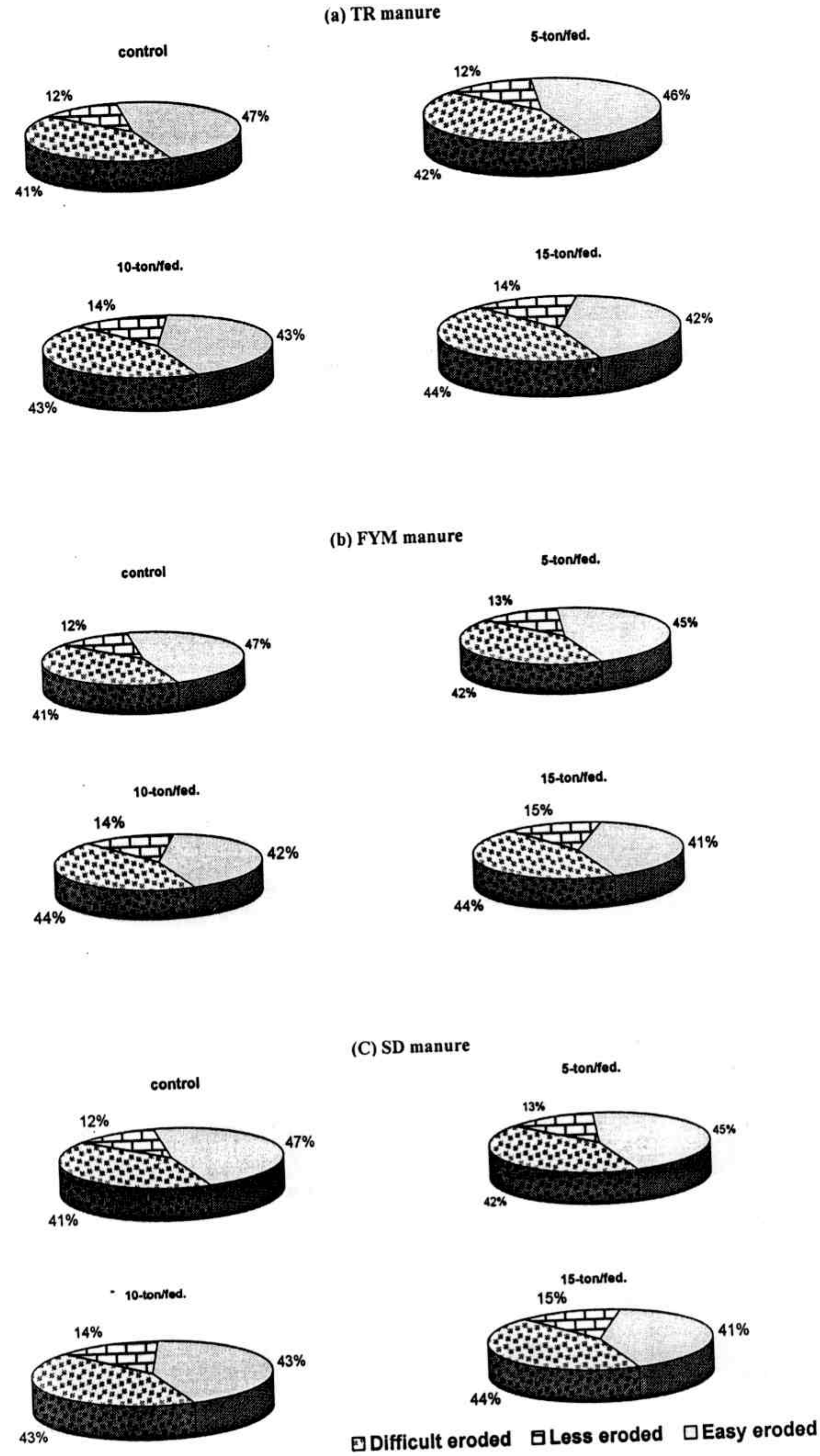


Fig.(15): Influence of compost types, application rates and 50% depletion level with biofertilization on soil erodibility.

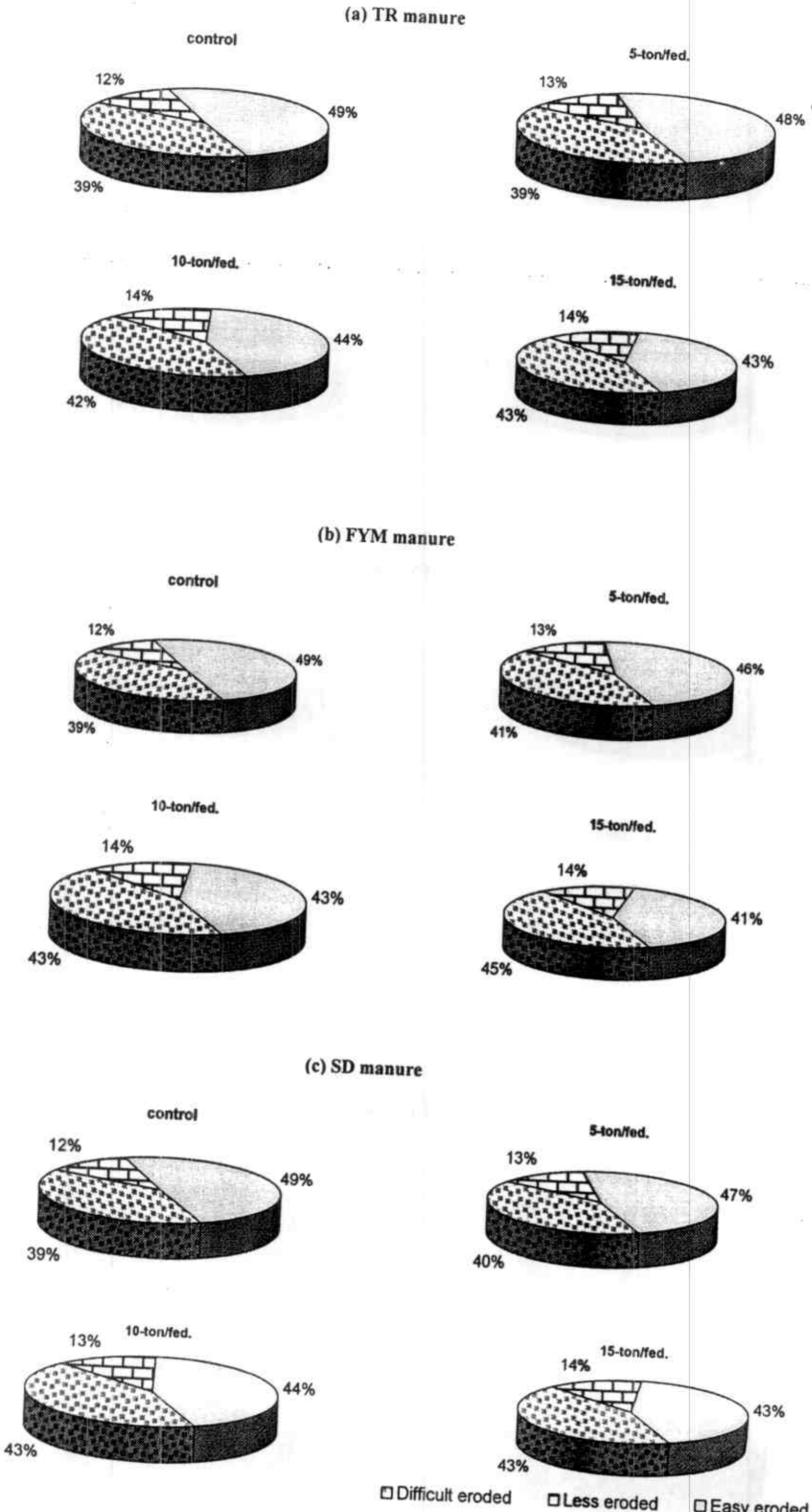


Fig.(16): Influence of compost types, application rates and 70% depletion level with biofertilization on soil erodibility.

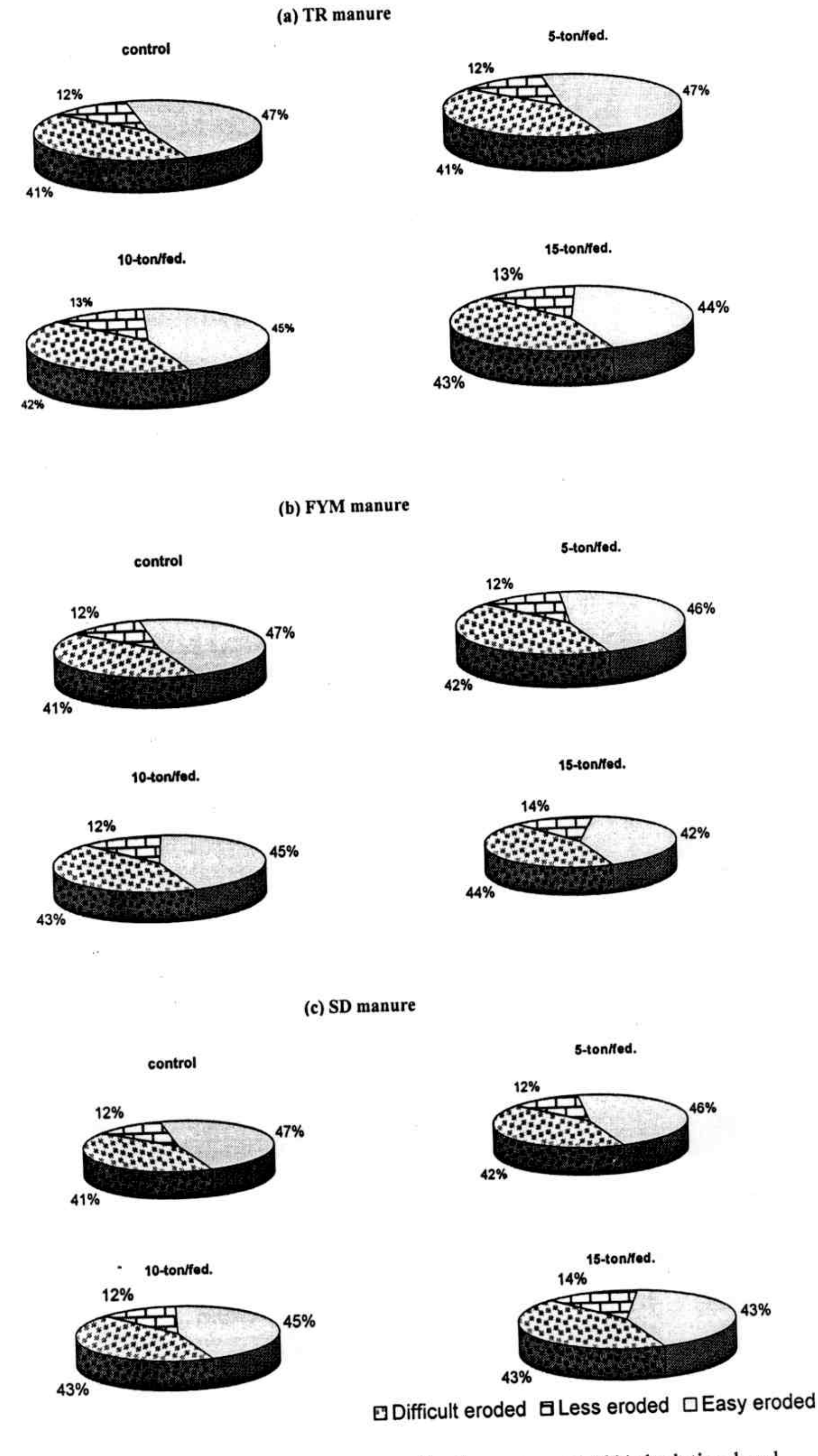


Fig.(17): Influence of compost types, application rates and 50% depletion level without biofertilization on soil erodibility.

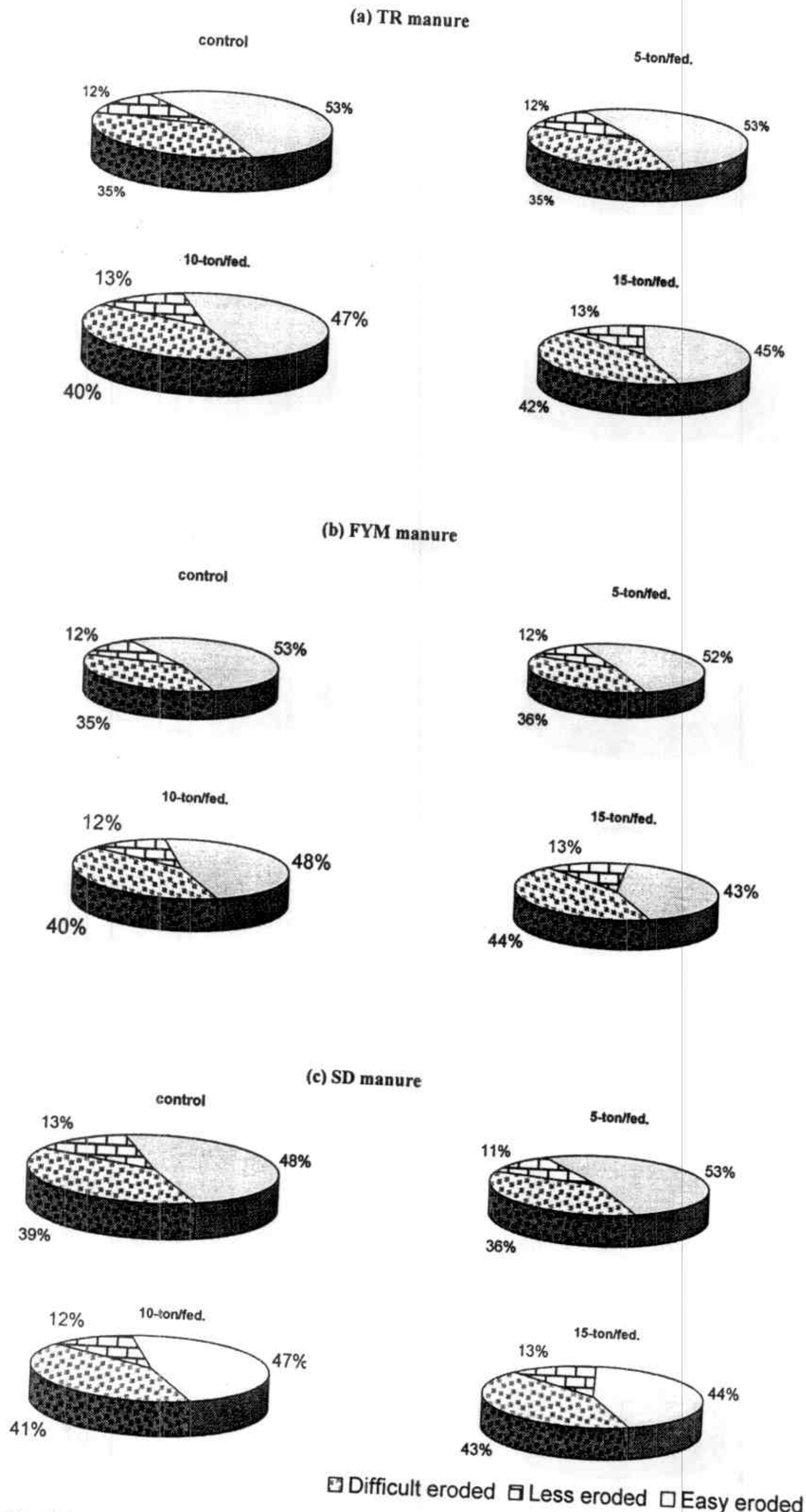


Fig.(18): Influence of compost types, application rates and 70% depletion level without biofertilization on soil erodibility.

The irrigation regimes as interacted with organic composting additions tend to promote the formation of difficult and less erodible grains of soil treatments under 50 % depletion more than the corresponding ones under 70 % irrigation water depletion. Whereas, the increasing percent in the soil aggregate fractions, that resist wind erosion i. e. (difficult and less eroded soil grains) amounted 10 and 6 % (as mean values) pertaining to the former and the latter irrigation regime, respectively. Concomitantly, the decreasing percent in the easy erodible soil aggregate fractions amounted also 10 and 6 % for the two irrigation regimes, respectively. This in turn, emphasized that the calcareous soil must be managed by organic compost addition with higher rate of 15 tons/fed. and at irrigation frequency, especially at 50 % depletion of soil available water as a recommended level to protect such soil from erosion impact. These results are compatible with those of Perfect *et al.* (1990), Haynes *et al.* (1991) and Gabriels and Michiels (1991). As regard to the biofertilizer application the soil erodibility data clarified that using this technique as concomitance with organic composting additions, get the better of composting treatments only, i.e., without biofertilization. Whereas, the soil treatments under such technique achieved 12 % increase in the formation of the difficult and less erodible aggregate fractions, while 5 % increase only in the same soil aggregate fractions occurred under the unbiofertilizated ones. In addition, the reduction in easily erodible aggregate fractions of the compost treated soil was higher at biofertilization system (11 %) than at unbiofertilization one (5 %). These trends of increasing soil grains, which considered more erodible resistance and diminishing the easier erodible ones by the aid of composting-biofertilizer technique are of the beneficial solution for erosion control. The findings of Abd El-Hamid (1995), Giusquiani *et al.*(1995), Abd El-Ghany *et al.*

(1997) and Martinez-Mena *et al.* (1998) go in the same direction of the last trend. They stated that using of the farmyard manure and urban waste as compost led to increase stability of soil aggregates, consequent strongly stand against erosion action. The bacterial inoculations into soil could support the role of the organic composting application.

Under biofertilizer treatments, the statistical analysis shown in Table (23) indicated that the effect of compost type (T) and rate (R) were significant factor affecting the formation of difficult erodible, less erodible and easily erodible grains of the soil. However irrigation regime (D) was of little effect on soil erodibility. Concurrently the interaction between three last factors was significant to high significant in most cases, i.e., strongly affect the different soil erodible grains. While at the condition of without biofertilization, the statistical results emphasized the high significant of compost rate (R) and depletion level factors (D) in influencing the different degree of soil erodible grains, regardless the type of compost (T). The interaction between every two or three variables in affecting soil erodibility was significant to highly significant trends.

Thus, it could be concluded that the formation of soil grains that able to resist erosion in calcareous soil was the function of the compost quantity added and the suitable irrigation regime applied, under any type of compost used. Also, the refreshment of the composted soil with the beneficial microorganisms, as biofertilization was of the vital processes to improve top soil structure, subsequently erosion control. In this accord, Hassett and Banwart (1992) reported that, because some erosion is inevitable, as long as, rain falls and wind blows, consideration should be given to

Table (23): Values of LSD of classified soil erodibility as affected by the experimental variables.

Biofertilization	Erodibility class	D	T	R	D X T	D X R	T X R	T X D X R
With	Difficult	11.919 ns	0.1182 ***	3.642 ***	0.1182 ns	3.642 ***	3.632 ns	3.642 ns
	Less	0.0355 ns	0.0301 ***	0.0705 ***	0.0301 **	0.0705 **	0.0705 *	0.0705 *
	Easy	0.0379 **	0.163 ***	0.2469 ***	0.163 ns	0.2469 ***	0.2469 ***	0.2469 ***
Without	Difficult	1.1306 **	0.4145 ns	0.4777 ***	0.4145 ns	0.4777 ***	0.4777 *	0.4777 ns
	Less	0.1026 **	0.0122 ns	0.0375 ***	0.0122 *	0.0375 ***	0.0375 ***	0.0375 ***
	Easy	0.1773 ***	0.2228 **	0.266 ***	0.2228 *	0.266 ***	0.266 **	0.266 ***

Where:

N = 144

D = depletion level.

T = compost type.

R = compost rate.

*Sig. 0.05 ** Sig. 0.01 ***Sig. 0.005

D x T = interaction between depletion and compost type.

D x R = interaction between depletion and compost rate.

T x R = interaction between both compost type and rate.

T x D x R = interaction between the three variabls, i.e; compost ty depletion level and compost rate.

the fact that the natural process of soil formation is extremely slow. Soil formation is on the order of 1-cm of topsoil formed in 40 to 80-years or longer. It is far more prudent to reduce soil erosion to tolerable levels than to attempt to replace topsoil.

The correlation and regression statistical study was conducted to evaluate the relationship between organic carbon and soil erodible fractions as illustrated in Figs. (19, 20 and 21). The obtained data indicate positive linear relations between the soil grains that difficult and less eroded with organic carbon percent and negative linear relation effect of soil grains that easy eroded and organic carbon percent. It could be concluded that the addition of organic composts markedly increased the soil resistance to erosion because of increasing the amounts of soil grains that resist erosion and decreasing the other soil grains those easy erodible ones. The correlation coefficients of such relation amounted 0.677, 0.753 and 0.744, pertaining to difficult, less and easy erodible grains, respectively. The regression equations described these tight significant relations were as following:

$Y= 6.621\,X + 37.7$, (difficult eroded grains)

$Y= 2.714\,X + 11.370$, (less eroded grains)

$Y= -9.335\,X + 50.921$, (easy eroded grains)

Where, (X) is the organic carbon percent and (Y) is the percent of soil fractions. This emphasized that the formation of erosive resistance soil grains depends mainly on the increasing rates of organic composts, i. e., increasing percent of organic carbon content in the soil.

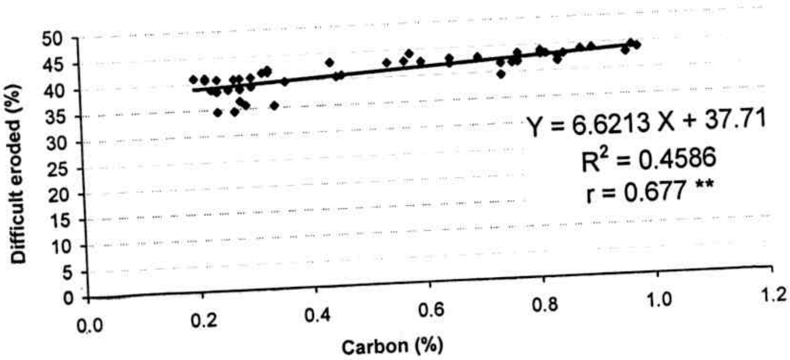


Fig (19): Relation between organic carbon percentages and difficult eroded soil grains.

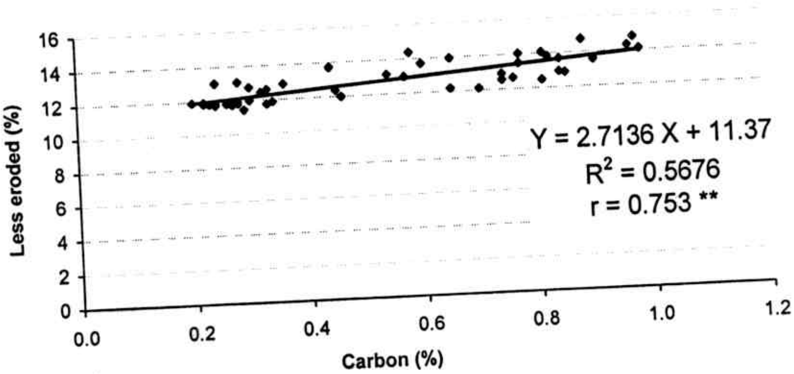


Fig (20): Relation between organic carbon percentages and less eroded soil grains.

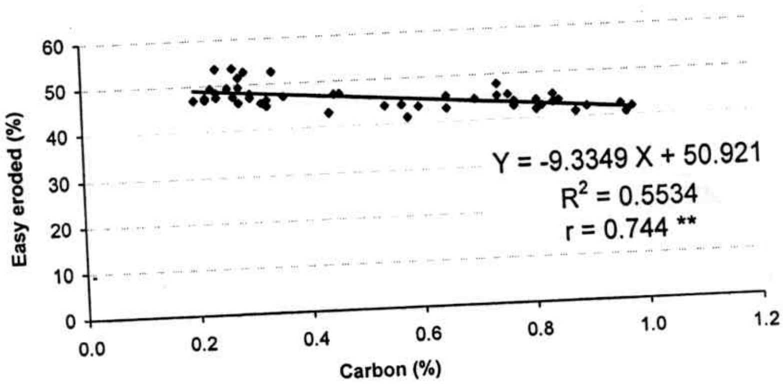


Fig (21): Relation between organic carbon percentages and easy eroded soil grains.

4. 2. Crop production:

The summary of crop yield components as affected by compost type, addition rates, irrigation water depletion levels and biofertilization treatments can be shown as following:

Table (24): Influence of composting types and addition rates, irrigation water depletion levels and biofertilization on sunflower plant components:

Crop components	Compost types		
	Town refuse	Farmyard	Sheep dung
Seed weight (ton/fed.)	1.317	1.398	1.552
Increase percent	96 %	108 %	131 %
Oil content	40.30	40.73	41.66
Increase percent	6 %	7 %	10 %
Shoot weight (kg/fed.)	753.000	1077.083	1283
Increase percent	37 %	95 %	133 %
Root weight (kg/fed.)	282.667	275.75	294.417
Increase percent	119 %	114 %	128 %

Crop components	Compost rates (ton/fed.)			
	0.0	5	10	15
Seed weight (ton/fed.)	0.673	1.273	1.434	1.557
Increase percent	------	89 %	113 %	132 %
Oil content (%)	37.97	40.1	40.90	41.63
Increase percent	------	6 %	8 %	10 %
Shoot weight (kg/fed.)	551	830.170	1036.167	1246.75
Increase percent	------	51 %	88 %	126 %
Root weight (kg/fed.)	128.985	248.667	287.117	316.264
Increase percent	------	93 %	123 %	145 %

Crop components	Irrigation water depletions	
	50 %	70 %
Seed weight (ton/fed.)	1.638	1.207
Increase percent	144 %	79 %
Oil content (%)	41.71	40.09
Increase percent	10 %	6 %
Shoot weight (kg/fed.)	1194.555	880.833
Increase percent	117 %	60 %
Root content (kg/fed.)	337.389	231.167
Increase percent	162 %	79 %

Crop contents	Biofertilization	
	With	Without
Seed weight (ton/fed.)	1.56	1.28
Increase percent	132 %	90 %
Oil content (%)	42.11	39.69
Increase percent	11 %	5 %
Shoot weight (kg/fed.)	1214.667	860.722
Increase percent	120 %	56 %
Root weight (kg/fed.)	315.167	253.389
Increase percent	144 %	96 %

4. 2. 1. Seed weights:

The data in Table (25) clarified that majority applying composted town refuse, farmyard manure and sheep dung resulted in increase seed weight as compared with control. The increasing by 96, 108 and 131 % over the control, respectively. However sheep dung was superior to the farmyard and town refused by 23 and 35 % respectively, While the increase of seed weight reached 12 % upper use farmyard manure.

As application rate of each compost increased from 0 to 5, 5 to 10 and 10 to 15 ton/fed., the mean increase in seed yield was achieved 89, 113 and 132 % irrespective of the type of compost. These results are in agreement with those of Strelnikov (1988), Buchanan and Gliessman (1990), Omar and Abo-Bakr (1991) and El-Sersawy *et al.* (1993). They attributed the increment in seed yield of sunflower to the improvement of soil physical properties due to organic matter additions and also to phosphohumic complex that minimize immobilization processes, anion replacement of phosphate by humate ions and coating of sesquioxide particles by humus forming a cover which reduces the soil phosphate-fixing capacity.

The application of irrigation water regime as, 50 % depletion from available water, interacted with different compost additions surpassed the other irrigation regime of 70 % depletion in getting high seed weights by over increasing percent of 65 %. These results are matched with those reported by El-Gabaly (1972), Vitkov (1976) and FAO (1979), as, they concluded that for high production of sunflower crop, soil water depletion should not exceed 45 % of the available soil water in calcareous soil. The biofertilization technique on soil treatments behaved as a good complemental

Table (25): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on seed weight and oil content of sunflower crop.

Biofertilization	Yield parameter	Depletion levels	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	Seed weight (ton/fed.)	50 %	1.28	1.44	1.64	1.77	1.78	1.91	1.93	1.62	1.73	1.77
		70 %	0.42	1.26	1.35	1.49	0.87	1.18	1.49	1.51	1.65	1.74
	Oil content (%)	50 %	41.00	41.35	41.70	43.00	41.75	42.00	43.90	42.80	43.50	44.10
		70 %	39.00	40.40	41.07	41.15	40.60	41.45	42.20	41.70	42.30	43.00
Without	Seed weight (ton/fed.)	50 %	0.79	1.31	1.54	1.74	1.42	1.55	1.77	1.38	1.56	1.62
		70 %	0.20	0.70	0.76	0.80	0.66	0.99	1.23	1.33	1.35	1.36
	Oil content (%)	50 %	36.30	39.75	41.10	40.50	40.00	40.50	41.00	40.80	41.10	41.90
		70 %	35.60	37.00	37.60	39.00	37.60	38.35	39.40	38.20	40.18	40.40

factor beside the effect of other factors for increasing seed yield, whereas it led to 42 % increase as compared with the unbiofertilization ones.

The results of Koreish *et al.* (1995) and El-Sersawy *et al.* (1996) Supported the aforementioned results, as they found highest significant increase in yield by soil inoculation with phosphate dissolving bacteria and mycorrhiza.

From the data in Table (26) indicated that the treatments either with biofertilization or without biofertilization were significant effect on weight seed of sunflower. The single effect of each of compost types (T), addition rates (R) and irrigation water depletion (D) on weight seed were significant.

Table (26): Values of LSD of seed weight as affected by the experimental variables.

Biofertilization	D	T	R	D x T	D x R	T x R	T x D x R
With	0.0717	0.0788	0.0478	0.1364	0.0676	0.0828	0.1171
	***	ns	***	**	***	*	***
Without	0.1014	0.0298	0.0302	0.0516	0.0428	0.0524	0.0741
	**	***	***	***	*	***	***

*Sig. 0.05

** Sig. 0.01

***Sig. 0.005

4. 2. 2. Oil content:

The mean values of seed oil content as affected by different treatments (Table 25), revealed that using composted town refuse, farmyard manure and sheep dung in calcareous soil caused 6, 7 and 10 % increase in oil content of sunflower plant associated with application relative to control, respectively.

It is also evident that increasing the application rates of such composts from 5 to 10 and 15 ton/fed. led to an increase in oil content by 6 to 8 to 10 % increase. These results are concomitant with those of Abou-Bakr and Omar (1996) and Muni and Sushil (1997) as, they concluded that the addition of city refuse and farmyard manure as composts by 10 or 20 tons/fed., led to significant increase in oil yield of sunflower cultivated in calcareous soil.

The data also showed that the application of irrigation water depletion as 50 %, from soil available water, led to suitable interaction with organic composts at various rates as compared with the other water depletion of 70 % whereas the former led to 10 % increase in oil content while the latter gave 6 % increase only. The application of biofertilization soil treatments was also of great importance for increasing oil content. Under such condition the seed resulted 11 % increase in oil content, while the unbiofertilized treatments gave 5 % increase as compared with control. These results are concurrent with those of Abdel-Gawad *et al.* (1989), El-Wakil *et al.* (1989), El-Kommos and Nour El-Din (1990), Attia *et al.* (1994) and Ashoub *et al.* (2000) where they reported that both seed oil yields were increased by decreasing the irrigation intervals. In addition, upon increasing water stress the photosynthesis decreased and respiration increased causing a reversal effect on seed and oil yields. In addition, Kucey (1988) referred the increase in plant dry matter and other crop components to the phosphate dissolving bacteria inoculation which it was able to reduce pH and hence the solubility of phosphates in soil medium.

4. 2. 3. Shoot Weights:

The data of sunflower shoot weights (Table 27) showed the great response to compost types and application rates where a high improvement in plant growth, subsequently shoot weights against the control was recorded. The town refused, farmyard and sheep dung achieved an increase of 37, 95 and 133 %, respectively. Each increment rate, i.e., from 5 to 10 to 15 ton/fed. led to 37 and 38 % increase in shoot weight at every changing rate. Under these organic treatments the application of irrigation regime as 50 % depletion level surpassed the 70 % depletion level in increasing shoot weight by 57 % due to the adequate soil moisture supply in the former case than the latter. Janardhan *et al.* (1986) and Singh and Singh (1989) reported that soil water deficit significantly decreased the mean area of leaves, Weight of plants, delayed flowering of the uppermost branch heads, number of seeds per plant and number of heads/plant of safflower.

The application of biofertilizer as a supplementary technique with organic composting addition caused a beneficial effect on sunflower growth and shoot yield, where it achieved an increase amounted 64 % over the unbiofertilized treatments.

Table (27): Influence of types and addition rates of compost materials, irrigation water depletion levels and biofertilization on shoot and root weights of sunflower crop.

Biofertilization	Yield parameter	Depletion levels	Control	Town refuse (TR)			Farmyard manure (FYM)			Sheep dung (SD)		
				Addition rates (ton/fed.)								
				5.0	10.0	15.0	5.0	10.0	15.0	5.0	10.0	15.0
With	Shoot weight (kg/fed.)	50 %	663	772	857	942	1072	1508	1899	1395	1838	2504
		70 %	526	646	755	895	773	1138	1275	1015	1069	1511
	Root weight (kg/fed.)	50 %	216.0	333.0	365.0	373.0	320.0	342.0	443.0	348.0	384.0	401.0
		70 %	80.4	207.0	300.0	308.0	171.0	200.0	215.0	250.0	355.0	358.0
Without	Shoot weight (kg/fed.)	50 %	520	610	730	825	760	1100	1210	950	1130	1400
		70 %	495	559	700	745	630	750	810	780	859	945
	Root weight (kg/fed.)	50 %	166.0	302.0	313.0	363.0	284.0	337.0	423.0	235.0	250.0	257.0
		70 %	21.5	154.0	182.0	192.0	180.0	187.0	207.0	200.0	240.0	255.0

4. 2. 4. Root weights:

The effect of compost types and application rates on root weights of sunflower was shown in Table (27). The data clarified that a good response of roots to town refuse, farmyard and sheep dung composts whereas, the increase in root weights amounted 119, 114 and 128 % comparing with the control, respectively. By changing the application rate from 5 to 10 ton/fed. the root weights modified with 30 % and as the rate changed from 10 to 15 ton/fed., the root modification reached to 22 % relative to the control.

The variation in irrigation water regimes as 50 or 70 % depletion from soil available water was very effective on root weights where, the former regime surpassed the latter one by 83 %. This could be attributed to the inter action effect of organic composts, especially as gradual composting application rates with the high soil moisture content under depletion level of (50 %) which made an adequate condition for root growth. Gregory *et al.* (1999) reported that the crop components increases were in response to amendment treatments and it may be due to availability of nutrients and other soil physical properties improvement such as bulk density, stable aggregates and water holding capacity.

The effect of biofertilization on root growth and weight under the last treatments of organic composts and irrigation regimes seemed to be more essential which resulted 48 % increase in root weights over the treatments of unbiofertilization. These results matched the other ones of Fawaz *et al.* (1980), Kucey (1988), Elwan (1988), Mahey *et al.* (1989), Tomar *et al.* (1997) and Singh *et al.* (1997) whose reported that phosphate-dissolving bacteria can be solubilize P and enhance its absorption by plant roots. These bacterial strains can able to increase shoot and root growth of inoculated plants as compared with the uninoculated ones.

The statistical analysis was given in Table (28) showed the effect of depletion levels (D) and rates of compost (R) and they were highly significant while type of compost (T) was with biofertilizer unsignificant the effect. In regard to the second and third interaction the data indicated the necessity and significant of the depletion levels (D) with increasing rate of compost (R). Whereas, the data clarified that the compost rate (R) was the greatest factor affect on root of sunflower followed by the depletion levels (D) while the type of compost (T) come after that expressing less factor in affecting weight of root.

Table (28): Values of LSD of weight of root as affected by the experimental variables.

Biofertilization	D	T	R	D x T	D x R	T x R	T x D x R
With	18.395	9.287	11.051	16.085	15.629	19.141	27.070
	**	***	***	***	ns	***	***
Without	40.361	21.306	11.980	36.903	16.942	20.750	29.344
	**	ns	***	***	***	ns	***

*Sig. 0.05

** Sig. 0.01

***Sig. 0.005

From the a aforementioned data of soil penetration resistance, it was cleared that under different composting types and application rates especially with using biofertilizer, the values of soil resistance to penetration decreased, indicating favorable conditions for roots growth. To express mathematically the relationship between sunflower roots (Y) kg/fed. and penetration resistance in kg/cm^2 the correlation and regression analyses were performed. The results indicated significant negative linear relation between the values of penetration resistance and root weights under all the experimental treatments. The obtained regression equation was as following:

$$Y = -9.756\ X + 758.384$$

Where, (Y) is the root weights (kg/fed.) and (X) is the penetration resistance of soil.

To express quantitatively the relationships between soil organic carbon, as the end product of composting decomposition, and any of seed weights (ton/fed.) oil content (%), shoot weights (kg/fed.) and root weights (kg/fed.) of sunflower, the correlation and regression analyses were carried out and the obtained results are illustrated in Figs. (22, 23, 24 and 25). The correlation analysis emphasized a significant relationship between soil organic carbon and the different yield components. The correlation coefficients between the two variables amounted 0.670^{**}, 0.599^{**}, 0.670^{**} and 0.729^{**}, pertaining to seed weights, oil content, weight of shoot and roots. The obtained linear regression equations were as following:

$Y1 = 1.251\ X + 0.581$, (for seed weights)

$Y2 = 5.187\ X + 37.456$, (for oil content)

$Y3 = 1073.0\ X + 354.950$, (for shoot weights)

$Y4 = 297.06\ X + 88.093$, (for root weights)

Where, X, Y1, Y2, Y3 and Y4 were the organic carbon percent, seed weights, oil content, shoot weights and root weights respectively.

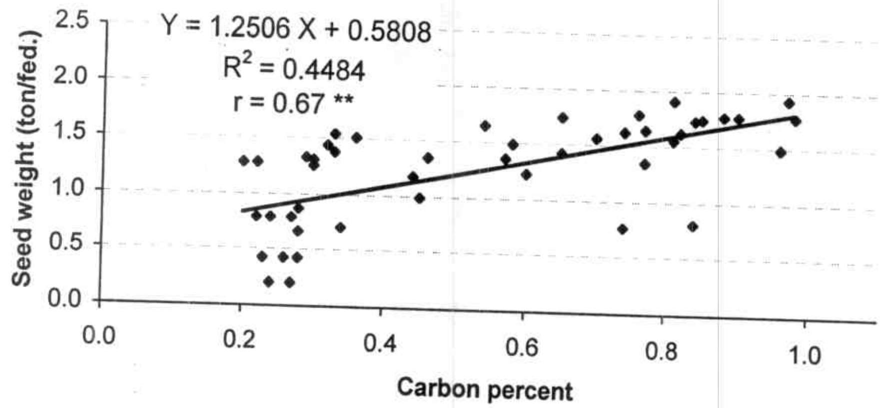


Fig. (22): Relationship between seed weights of sunflower and soil organic carbon percentages.

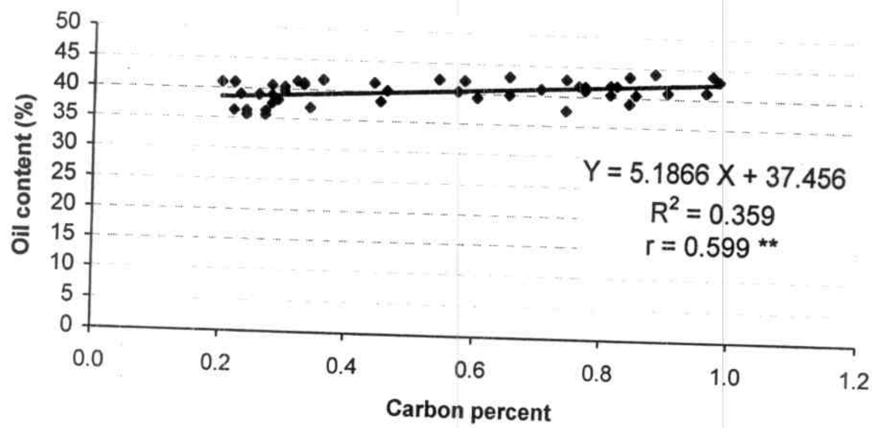


Fig. (23): Relationship between oil content of sunflower and soil organic carbon percentages.

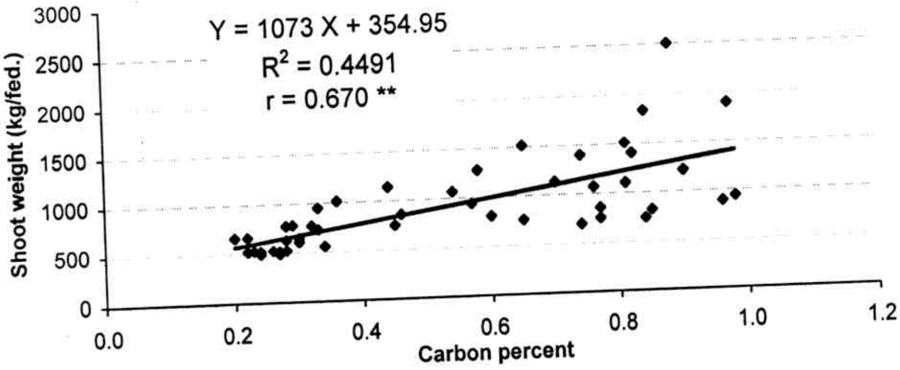


Fig. (24): Relationship between shoot weights of sunflower and soil organic carbon percentages.

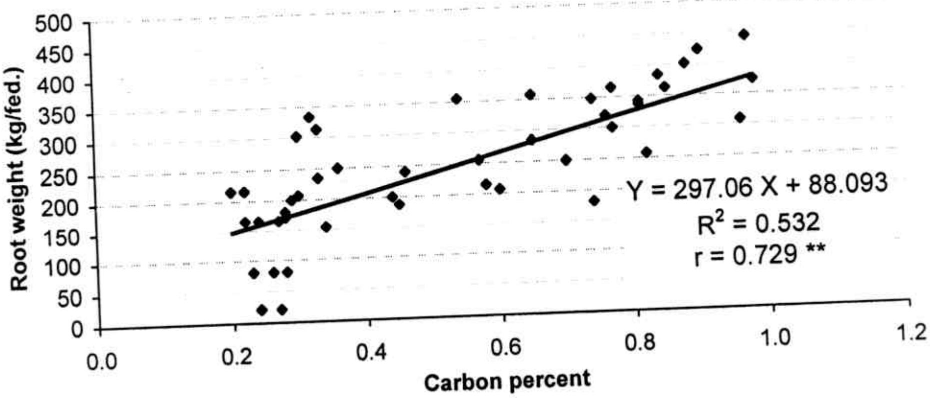


Fig. (25): Relationship between root weights of sunflower and soil organic carbon percentages.