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EFFECT OF ALGAL INOCULATION AND DIFFERENT WATER HOLDING CAPACITY LEVELS ON SOIL AGGREGATION AND SOIL MOISTURE CONTENT OF SANDY AND CALCAREOUS SOILS UNDER TOMATO CULTIVATION CONDITION

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ABSTRACT

A twenty four weeks pot experiment was carried out to study the effect of algal inoculation under different water holding capacity (WHC) levels *i.e.* 75% -100% on soil aggregation and moisture content of sandy and calcareous soils under tomato cultivation condition. Results revealed that in sandy soil, *Nostoc muscorum* gave higher field capacity of 9.53 and 9.91% in respective to 75 and 100% WHC levels than those of 8.40 and 8.12% given by *Chlorella pyrenoidosa* at the same levels of WHC. Similarly, *N. muscorum* gave higher available water percentages of 5.93 and 6.94 against 5.48 and 5.63 for *C. pyrenoidosa* at 75 and 100% WHC, respectively.

In calcareous soil, also *N. muscorum* was superior to *C. pyrenoidosa* in affecting both field capacity and available water percentages at 75 and 100% WHC levels. In sandy soil, inoculation with algae increased fine capillary pores (< 0.19 μ) and water holding pores (8.60 – 0.19 μ), whereas the quickly drainable pores (< 28.8 μ) being decreased at both 75 and 100% WHC levels. Same trends were observed in calcareous soil. In both sandy and calcareous soils, algal inoculation increased the stability index, while decreased the instability index compared to control at 75and 100% WHC, meant that algal inoculation improved the soil particles aggregation. These results are recorded at tomato harvest time (24 weeks from transplanting).

Keywords: Algal inoculation - Soil aggregates stability - Soil moisture content - tomato cultivation

INTRODUCTION

Water stable aggregates structure has been considered as a major factor that influence soil productivity, it can be considered the key of soil fertility. The formation, size and stability of soil aggregates are influenced by various physical and environmental conditions of soil (Omar, 1990).

The enter woven soil algal growth such as *Schizothrix california,* consolidate the soil surface, leading to the formation of the soil crust which is especially evident where vascular plants do not form a continuous ground cover. This alga-stabilized surface layer improve soil aggregates, infiltration, decreases runoff. Algae produce surface humus after death exert solvent action on certain soil minerals, maintaining reserve supply of elements in a semi-available form for higher plants (Shields and Durrell, 1964). Schulten (1985) reported that, fungi and cyanobacteria can make soil unwettable and decrease infiltration. Finally, upon its death and decay, the organism increases organic matter in the soil (Kleiner and Harper, 1972). Studies on the mechanisms for soil aggregation leave many gaps in knowledge. There is a mechanical component, since filaments or rhizoids from a network around soil particles. Cyanobacteria that from sheath or a slime with exopolysaccharides around their cells are suitable for the latter process (Schulten, 1985). Studies on extra- cellular polysaccharides from cyanobacteria have dealt largely with chemical composition (Nakagawa *et al.*, 1987 and Panoff *et al.*, 1988) and ultrastructural descriptions of extra-cellular layers formed by the accumulation of various types of polymeric substances around cell walls and their protective role (Potts, 1994). Sudo *et al.*, (1995) isolated a cyanobacterium that produces large quantities of exopolysaccharides and studied the influence of culture medium, particularly its NaCl concentration, on production of the exopolysaccharide.

Only a few studies have been made on the effects of algal mass inoculation on soil aggregation. *Oscillatoria prolifica* and *Nostoc commune* increased water stability of aggregates when they were grown separately on Peoria losses soils (Bailey *et al.*, 1973). The effects of *N. muscorum* mass on soil physical, chemical and biological properties indicates the possible benefits of cyanobacteria as soil inoculants (Roger and Burns, 1994). The increase in soil aggregate stability is probably due to the extra cellular substances produced by *N. muscorum*, mainly to the exopolysaccharides (Cano *et al.*, 1997). However, there is apparently no literature on the effects of isolated *N. muscorum* exopolysaccharides on soil aggregates stability. Barclay and Lwin (1985) Reported that many intensively farmed soils tend to have an acidic PH because of the use of ammonium fertilizers. Certain polysaccharide-producing species of green algae may therefore be better candidates for soil amendment applications because they grow relatively fast in environment ranging from pH 6.0 to 8.0. The soil aggregation is more pronounced in cultivated soils than the non cultivated ones. This behavior could be due to the root exudates which increase the microbial population in rhizosphere area. This increase in soil microorganisms is supposed to increase the exopolysaccharides that act as a binding and glue agents for soil particles (Omar, 1990).

The present work is to study the effect of algal inoculation (*Nostoc muscorum* or *Chlorella pyrenoidosa*) and different water holding capacity levels(*i.e.* 75 and 100%) on soil aggregation and moisture content of sandy and calcareous soils under tomato cultivation condition.

MATERIALS AND METHODS

A twenty four weeks pot experiment was conducted in the greenhouse at Agric. Res. Center, Giza, Egypt to predict the effect of algal inoculation and different water holding capacity levels on soil aggregation and moisture content of sandy and calcareous soils under tomato cultivation condition. Chemical characteristics and soil particle size of the two soils are present in Tables (1and 2). Pots of 25 cm diameter were filled with 4 kg soil from each of sandy or calcareous soils. Soils in pots were kept at 75 and 100 % WHC. Five tomato seedlings cultivar (Giza s_{12}) were transplanted in each pot. One week later, tomato plants were thinned to three plants and then inoculated with either *Nostoc muscorum* or *Chlorella pyrenoidosa* according to the following treatments:-

1) Control 100% WHC (without algal inoculation)
2) Control 75% WHC (without algal inoculation)
3) *Nostoc muscorum* + 100% WHC
4) *Nostoc muscorum* + 75% WHC
5) *Chlorella pyrenoidosa* + 100% WHC
6) *Chlorella pyrenoidosa* + 75% WHC

At harvest (after 24 weeks from tomato transplanting) the soils were analyzed for physical properties such as soil moisture content percentage (Richards, 1954), pore size distribution (Deleenheer and Deboodt, 1965) and Soil aggregate stability (Richards, 1954).

Table (1): Chemical properties of sandy and calcareous soils

Soil type	pH 1: 2.5	E.C. dS m^{-1}	Cations meq L^{-1}				Anions meq L^{-1}			
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	CO_3^{--}	HCO_3^{-}	Cl^{-}	SO_4^{--}
Sandy	8.70	4.30	19.00	10.05	14.00	1.95	0.00	9.05	14.60	21.35
Calcareous	7.8	6.25	42.25	3.90	15.10	1.40	0.00	2.25	26.30	34.10

Table (2): Soil particle size distribution for sandy and calcareous soils

Soil type	Soil Particle size mm						
	8 - 2	2 - 1	1 – 0.5	0.5–0.25	0.25–0.125	0.125–0.063	> 0.063
Sandy	0.0	15.6	15.0	25.5	20.4	8.45	15.05
Calcareous	5.05	20.5	14.5	24.5	25.0	5.0	5.45

RESULTS AND DISCUSSION

At tomato harvest time (twenty four weeks after transplanting, soils were sampled for physical properties determination.

The soil moisture percentage Table (3) is expressed as available water percentage which is consequently calculated as the difference between soil moisture content resulted by the suction pressure of 0.10 bar on the soil particles (field capacity) and the soil moisture content at wilting point (15.00 bar suction pressure).

In sandy soil, results revealed that algal inoculation increased the moisture content percentage for field capacity over the control treatments at both 75 and 100% WHC levels. However, *N. muscorum* inoculation achieved higher field capacity of 9.53 and 9.91% in respective to 75 and 100% WHC than those given by *C. pyrenoidosa* at same WHC levels (8.40 and 8.12%).

Same as observed with field capacity, the soil available water content percentage gave the highest per cent of 5.93 and 6.94 at 75 and 100% WHC levels, respectively, for *N. muscorum* against 5.48 and 5.63% at the same levels, for *C. pyrenoidosa*. These mentioned available water percentages were also higher than those of control treatments at same WHC levels.

In calcareous soil, the behavior of the soil moisture content percentage at both field capacity and available water was similar to that noticed with sandy soil, since algal inoculation led to increase both soil field capacity and available water percentages over the control treatments at both tested moisture levels (75 and 100% WHC). On the other hand, *N. muscorum* inoculation was superior to *C. pyrenoidosa* in affecting both field capacity and available water percentages at both 75 and 100% WHC levels. However, the obtained field capacity percentages due to *N. muscorum* were 27.89 and 27.87 against 26.02 and 26.71% for *C. pyrenoidosa* at both of 75 and 100% WHC levels.

Table (3): Effect of algal inoculation on soil moisture content (%) on sandy and calcareous soils as affected by different water holding capacity levels under 24 weeks of tomato cultivation.

Algae strains	WHC (%)	Moisture content at different applied suction (atm bar/cm)						(***AW)
		0.001	0.10 *FC	0.33	0.66	1.00	15.00 **WP	
Sandy soil								
Control	75	22.75	7.18	4.41	4.01	3.78	2.92	4.26
	100	20.33	7.55	4.63	4.40	4.03	3.17	4.38
C. pyreanoidos	75	23.50	8.40	5.70	4.27	3.88	2.92	5.48
	100	19.58	8.12	4.85	3.72	3.26	2.49	5.63
N. muscorum	75	21.01	9.53	5.82	4.37	3.84	3.60	5.93
	100	22.46	9.91	5.00	3.74	3.25	2.97	6.94
Calcareous soil								
Control	75	43.46	24.23	26.71	25.82	24.2	12.21	12.02
	100	34.66	24.62	19.94	19.74	19.07	12.53	11.09
C. pyreanoidos	75	32.54	26.02	21.69	20.86	19.64	13.27	12.75
	100	36.07	26.71	23.24	22.88	22.23	14.09	12.62
N. muscorum	75	41.86	27.89	23.02	21.85	20.64	14.25	13.64
	100	38.27	27.87	23.56	22.53	20.82	14.56	13.31

*** FC : Field capacity**
****WP : Wilting point**
*****AW : Available water = FC - WP**

Due to the soil available water percentage, *N. muscorum* gave higher percentages of 13.64 and 13.31 than those of 12.75 and 12.62 for*C. pyrenoidosa* when both tested at 75 and 100% WHC levels, respectively.

In concern to pores size distribution percentages (Table 4), in sandy soil, inoculation with either *C. pyrenoidosa* or *N. muscorum* increased fine capillary pores (< 0.19 ?) and water holding pores (8.62 – 0.19 ?) whereas the quickly drainable pores (< 28.8 ?) decreased, at both tested moisture levels of 75 and 100% WHC in comparison with the control treatments. For instance, the fine capillary pores and water holding pores percentages recorded by *N. muscorum* were 14.24 and 13.47 at 75% WHC along with 14.45 and 11.86 at 100% WHC, respectively, against 12.97%, 6.57% and 12.62%, 7.18% for the control treatment at 75 and 100% WHC, respectively.

Table (4): Effect of algal inoculation on soil pore size (μ) distribution in sandy and calcareous soils under different water holding capacity levels after 24 weeks cultivation of tomato plants.

Algae strains	WHC (%)	QDP (>28.8μ)	SDP (28.8-8.62μ)	WHP (8.62-0.19μ)	FCP (<0.19μ)
Pore size (%)					
Sandy soil					
Control	75	68.17	12.29	6.57	12.97
	100	69.05	11.15	7.18	12.62
C. pyrenoidosa	75	64.22	11.49	10.82	13.47
	100	59.16	16.14	11.07	13.73
N. muscorum	75	60.33	11.96	13.47	14.24
	100	62.09	11.60	11.86	14.45
Calcareous soil					
Control	75	32.42	12.11	23.25	32.22
	100	31.94	13.52	21.36	33.18
C. pyrenoidosa	75	23.11	10.23	25.86	40.80
	100	25.94	9.62	25.36	39.08
N. muscorum	75	30.37	11.64	20.92	37.07
	100	27.17	11.26	23.51	38.06

QDP: Quickly drainable pores
SDP: Slowly drainable pores
WHP: Water holding pores
FCP: Fine capillary pores

However, no definite effect for both tested water holding capacity levels on soil pores size could be observed. In calcareous soil, same as in sandy soil, inoculation with either *C. pyrenoidosa* or *N. muscorum* increased both fine capillary pores (< 0.19 ?) and water holding pores (8.60 – 0.19 ?) percentages over the control treatment at both 75 and 100% WHC levels. While on the contrary, the algal inoculation decreased the quickly drainable pores (> 28.8 ?) percentages at both tested moisture levels. For instance *N. muscorum* at 75% gave 37.07% (fine capillary pores), 20.92% (water holding pores) and 30.37% (quickly drainable pores) against the corresponding pore size percentages of 32.22%, 23.25% and 32.42% for the control treatment, respectively. However, it seemed that both *C. pyrenoidosa* and *N. muscorum* had similar influence on the pore size percentage distribution in the calcareous soil.

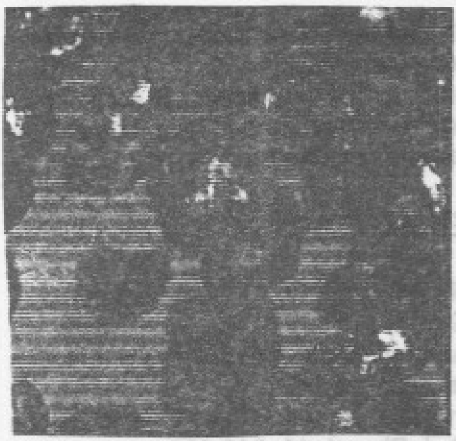
In the view of soil aggregates stability after tomato harvest (Table 5), in sandy soil), algal inoculation increased stability of particles aggregate at all moisture levels (75 and 100% WHC) over the control treatment. However, the stability index ranged between 0.31 and 0.49 for the control (75% WHC) and *C. pyrenoidosa* (75% WHC) treatments. Herin, The values of instability index were ranged between 2.02 and 3.13 for *C. pyrenoidosa* and the control treatments at 75% WHC level. Also, it was observed the algal inoculation decreased the instability index than the control treatments at both 75 and 100% WHC. The instability index values at 75% WHC along with algae inoculation were less and better than those recorded at 100% WHC level. On the contrary, the stability index values for algae inoculated treatments at both tested moisture levels were higher than those of the control treatments, meant that algae inoculation improved the soil particles aggregation. This phenomenon seemed to be superior with *C. pyrenoidosa* (75% WHC) followed by *N. muscorum* and *C. pyrenoidosa* at 100% for both. Their corresponding stability index values were 0.49, 0.43 and 0.43.

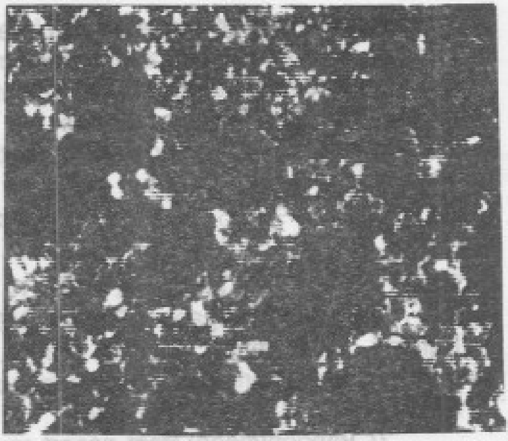
In calcareous soil, the instability index values in the algae inoculated treatments were less and better than those recorded by the control treatments at 75 and 100% WHC levels. However, the instability index ranged between 2.14 (control at 100% WHC) and 2.24 (control at 75% WHC). Herein, algal inoculation at both tested moisture level after tomato harvesting decreased the instability index values than those obtained by control treatment. However, this decrease was higher and better at 75% WHC level when combined with algal inoculation. This instability behavior appeared to be turned on the stability index values which was better in the algae inoculated treatment than those of non-inoculated ones at both tested moisture levels (75 and 100 WHC). However, the stability aggregate index ranged between 0.44 and 0.51 for control along with 75% and *N. muscorum* at 100% WHC.

Table (5): Effect of algal inoculation on some physical properties of sandy and calcareous soils after 24 weeks cultivation of tomato plants.

Algae strains	WHC (%)	Dry sieving	Wet sieving	Instability Index	Stability Index
Sandy soil					
Control	75	11.59	8.46	3.13	0.31
	100	16.55	14.15	2.40	0.41
C. pyrenoidosa	75	10.12	8.10	2.02	0.49
	100	14.25	11.95	2.30	0.43
N. muscorum	75	12.78	10.30	2.48	0.40
	100	10.39	8.09	2.30	0.43
Calcareous soil					
Control	75	14.64	12.40	2.24	0.44
	100	15.30	13.16	2.14	0.46
C. pyrenoidosa	75	13.67	11.55	2.12	0.47
	100	10.13	8.10	2.03	0.49
N. muscorum	75	10.35	8.25	2.10	0.47
	100	13.25	11.30	1.95	0.51

At 100% WHC *N. muscorum* gave the best stability index increase percentage of 10.51% compared to the control treatment against 6.90% at 75% WHC for *N. muscorum* treatment. Generally, the effect of algal inoculation in soil aggregates stability index seemed to be better in sandy soil than those obtained with the calcareous one, and that the moisture levels of 75% combined with *C. pyrenoidosa* gave the favorite percentage increase in stability index value (0.58%) compared to the control treatment. Algae could ameliorate the soil aggregates stability especially in sandy soil to some extent better than they act in calcareous soil. The microscopic investigation (10 x) for the soil particles inoculated with algae indicated the inter woven algae filaments that surrounded the soil particles compared to uninoculated ones (Fig. 1).





Soil non-inoculated with algae **Soil inoculated with algae**

Good soil structure is important for aeration, root development, and ease cultivation and may minimize or prevent soil erosion losses to wind and water. Soil conditioners are amendments that either alter soil structure or lower the surface tension of water. Unfortunately, most soil conditioners that alter structure are too expensive for common use in agriculture, and this why the microbiological processes that influence aggregation and soil erosion are accorded attention (Lynch and Bragg, 1985). Among these is inoculation with fast growing palmelloid microalgae of irrigated sandy or calcareous soils low in organic matter content that are prone to erosion by win or water (Metting and Raburn, 1983). In this study algae were inoculated to sandy and calcareous soils to improve their expected poor structure. Inoculation with either *N. muscorum* or *C. pyrenoidosa under* different WHC led to improve the soil moisture percentage, soil pore size distribution, soil stability aggregates and in turn soil structure. The Improvement of soil aggregate structure was more pronounced in sandy soil than in calcareous soil. This could be attributed to the heavy growth of algae which exert polysaccharides thereby improving soil aggregation, stimulate some beneficial soil microorganisms, improve soil water holding capacity and increase soil organic matter (Rao and Burns, 1990). Exopolysaccharide increases the soil organic matter content as a consequence of the sugar derived from the abundant slime mainly secreted by *N. muscorum* inoculated to soil in addition to the polymers produced by other microorganisms stemmed in soil in response to algae inoculation (Caire *et al.*, 1997). The result of Drew and Anderson (1977) indicate that soil moisture levels above 60 % of moisture holding capacity are necessary for growth of algae in soils. Brock (1975) reported that moisture levels near 100% of field capacity are necessary to maintain growth and respiration of soil algae. In this respect, 100% WHC was superior to *N. muscorum* against 75% WHC for *C. pyrenoidosa* to give the best soil aggregate stability index in calcareous soil. Omar (1983) reported that the stability of soil aggregates after potatoes is significantly than that after clover ,cotton, tomatoes and corn cultivated without biofertilizer, while inoculation with biofertilizer increased the soil organic matter, soil aggregates stability, water retention and consequently improved the soil structure. He owed these observation noticed with biofertilizer application to the exopolysaccharides secreted by biofertilizers especially those documented in case of algal inoculation applied in tomato cultivation.

Generally, algae when inoculated to the marginal poor soil such as sandy or calcareous soils has the ability to ameliorate their aggregates stability especially in sandy soil other than the calcareous one.

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تأثير التلقيح بالطحالب ومستويات مختلفة من الرطوبة علي تجمع الحبيبات و المحتوى الرطوبي للتربة الرملية و الجيرية تحت ظروف زراعة الطماطم

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أجريت تجربة في الصوبة لدراسة أثر تلقيح أي من التربة الرملية أو الجيرية بالطحالب عند مستويات رطوبة مختلفة هي ٧٥ % ، ١٠٠% من السعة التشبعية للتربة علي بعض خواص التربة الطبيعية مثل المحتوى الرطوبي للتربة و توزيع الحبيبات ، و ثبات تجمع حبيبات التربة و قد أوضحت النتائج ما يلي :

١. حققت سلالة *Nostoc muscorum* في التربة الرملية أعلي سعة حقلية (٩,٥٣ ، ٩,٩١%) عند مستويات رطوبة (٧٥ ، ١٠٠%) علي التوالي ، عن السلالة *Chlorella pyrenoidosa* والتي حققت ٨,٤٠ و ٨,١٢ عند نفس المستوى من الرطوبة مقارنة بالسلالة الأخرى ٥,٤٨و ٥,٦٣ عند نفس المستويات.
٢. كذلك حققت سلالة *N. muscorum* أيضا أعلي كمية ماء متاح بالتربة الرملية (٥,٩٣ ، ٦,٩٤) عند مستوى رطوبة ٧٥ ، ١٠٠% من السعة الحقلية مقارنة بالسلالة الأخرى *Chlorella pyrenoidosa* والتي حققت ٥,٤٨ و ٥,٦٣ عند نفس المستويات.
٣. في التربة الجيرية حققت سلالة *N. muscorum* أعلي سعة حقلية عند مستويات الرطوبة تحت الإختبار بالمقارنة مع سلالة *C. pyrenoidosa* .
٤. أدى التلقيح بالطحالب إلي زيادة الحبيبات الشعرية (أقل من ٠,١٩ ميكرون) و تقليل الحبيبات ذات الحجم الكبير (أقل من ٢٨,٨) و ذلك في التربة الرملية مما يوضح زيادة قدرة التربة علي الاحتفاظ بالماء بعد التلقيح بالطحالب - و قد تحقق نفس الشيء في التربة الجيرية.
٥. أدى التلقيح بالطحالب في كل من التربة الرملية و الجيرية إلي زيادة حجم الحبيبات و بالتالي زيادة دليل الثبات لهذه الحبيبات و قلة دليل عدم الثبات لحبيبات التربة، وكل هذه النتائج تم التوصل إليها في أراضي مزروعة بالطماطم وأخذ منها العينات عند مرحلة الحصاد (٢٤ أسبوع من الشتل).