Menoufia J. Soil Sci.,Vol. 2 October (2017): 227 - 246

EFFECTIVENESS OF NATURAL SOIL CONDITIONERS AND IRRIGATION REGIME ON: 1- LOAMY SAND SOIL PROPERTIES, CROPS PRODUCTION AND WATER PRODUCTIVITY

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Received: May. 31, 2017 **Accepted: Jul. 2, 2017**

ABSTRACT: *Two field experiments were carried out at loamy sand soil, located at Baltim district, Kafr El-Sheikh Governorate. The experiments were occupied for conducting wheat and maize during winter and summer seasons of 2015/2016 and 2016 respectively. The main objectives of this investigation were to study and evaluate the effect of soil conditioner types, and their mixtures in sandy soil subjected to different irrigation deficits on the following parameters:* ***(i)*** *soil properties (chemical, physical and moisture constants, and* ***(ii)*** *agronomical production of wheat and maize and water productivity after full maturity in the studied soil under consideration. Four types of soil conditioners [bentonite, compost, polyacrylamide and their mixtures 1:1:1(w/w)] were applied before cultivation. Three levels of soil moisture depletion regimes were used (30, 50 and 70 %) from its available water capacity. Applying natural soil conditioner types, and their mixtures in the studied sandy soil subjected to moisture depletion regime realized improving soil chemical, physical and moisture content. Soil salinity (soil reaction, electrical conductivity and ionic strength), hazard sodium parameters (soluble sodium percentage and sodium adsorption ratio), soil porosity and available water capacity were increased. On the other hand, hydraulic conductivity and bulk density were decreased. Polyacrylamide treatment realized the superiority under wheat and maize field experiments. Irrigation after 50 % AWSMD gave moderate values of such properties between wet (30% AWSMD) and dry (70% AWSMD). Increasing grains, straw, grains weight and harvest index significantly for wheat and maize crops, because of adding soil conditioners compared with control. Results also indicated that, from view point of water and economic, the highest values of crop yield and water productivity were obtained from irrigation at 50 % depletion from its available water capacity rather than 30 % and 70 % respectively.*

Key words: *Sandy soils; Water productivity; Soil conditioners; Ionic strength; Wheat and maize.*

INTRODUCTION

Nowadays, the term of « sustainable agriculture » is widely used globally, which is keystone of the rational utilization of soils as one of our most important natural resources. It is the important aims of « sustainable agriculture » to protect and maintain of the multi-functions of soils (Várallyay, 2005). For preservation and sustainability, the productivity of soil we should take special regard to sandy soils having unfavorable properties. Sandy soil characterized by less than 18 % clay and more than 68 % sand in the first 100 cm of the soil depth are the poor soils that occur in many parts of the world (Van Wambeke, 1992). There are other problems facing agriculture sector caused by, mainly, inappropriate soil, water and fertile management practices as well as rapid decreasing of agricultural land particularly in Delta soils. Therefore, we must find rapid solutions to face these problems. Sandy soils hold little water as the large pore spaces allow water to drain freely from soil. The productivity of these soils is limited by low water holding capacities, high infiltration rates, high evaporation, low inherent fertility levels, very low organic matter content and excessive deep percolation losses. Also, the water use efficiency of the crops cultivated in such soil is low.

Tackling these problems can be achieved through applying organic amendments and soil conditioners. These materials improve the retentive capacities of these soils and allow plants to get their water requirements and phyto –available nutrients easily. Use of polyacrylamides as soil conditioner in many countries increased after the introduction of Krilium in 1951 (De Boodt, 1972). New generation polyacrylamides have high molecular weights and require low application rates. They also have important environment, soil conservation and irrigation efficiency benefits for general agriculture, making their use economically feasible (Sojka and Lentz, 1994). The properties of different types of polyacrylamides have been described by (Bouranis, 1997). The effect of cross-linked polyacrylamides on physical and chemical properties of sandy soils has been described by (Al-Omran and Al-Harbi, 1997). The use of cross-linked polyacrylamides has been tested to increase the water holding capacity of sandy soils (Silberbush *et al.,* 1993, Stewart, 1975, Taylor and Halfacre, 1986). Polyacrylamides in soil were also able to reduce the amount of water lost from the soil through evaporation (Al-Omran and Al-Harbi, 1997). Nevertheless, using this type of soil conditioner to amend Egyptian sandy soils is so far.

Bentonite – a rock containing mainly 2:1 clay mineral montmorillonite, a member of the smectite family – has been recognized in many countries as a very good amendment to improve the properties of such infertile sandy soils (BENKHELIFA *et al.,* 2008), (SALETH *et al.,* 2009, SATJE and NELSON, 2009)

Cereal crops such as (wheat and maize) are very strategically important crops in Egypt because it’s constituent and indispensable part of Egyptian food diet. Generally, there is a great gap between the consumption and production of such crops. On the other hand, it is worth noting that, the agriculture production in Egypt is mainly depend upon irrigated agriculture. The gap between supplies and demands of water is widening with increasing global population. Egypt suffering from this trouble, especially when we know that we are under water poverty limit. Because of the water limitation, one of the most important targets in the agriculture sector is how to save irrigation water and increase water use efficiencies. So, new techniques and practices are needed to achieve water save. Estimating irrigation water becomes important for project planning and irrigation management. The over irrigation practiced by the farmers usually leads to low irrigation efficiency. So, it is necessary to ascertain to what extent the water in the root zone can be depleted to produce high economic yield with using little water applied. Planning best irrigation regimes is very important for maintaining available irrigation water. The proper water management (irrigation scheduling) not only limits determination of crop water requirements but also helps to know when and how much water should be applied to get high efficiency of each unit of water. Regulated deficit irrigation is one of such practices. Many studies indicated that the deficit irrigation was a successful technique in crops irrigation, (Omran, 2005, Seif *et al.,* 2005).

The main objectives of this investigation were to study and asses the effect of natural soil conditioner types and their mixtures in sandy soils subjected to irrigation regimes on:

(i): Soil physico-chemical properties and moisture constants.

(ii): Agronomical production of wheat and maize crops after full maturity.

(iii): Crop water productivity of both wheat and maize

MATERIALS AND METHODS

2.1. Experimental design, agronomic practices and soil analysis:

A field experiment was conducted at Baltim district, Kafr El-Sheikh Governorate

31° 34 40.6 N latitude and 31° 10 55.5 E longitude with an elevation of about 3 meters above sea levels. The experiment has been conducted for wheat and maize during winter and summer seasons of 2015 /2016 and 2016 respectively. Before planting and after wheat and maize plants full maturity, representative composite disturbed soil surface samples were collected, air dried, crumbled by hand, homogenized and finely ground in steel mill to pass through 100-mesh (0.15 mm opening sieve) and thoroughly mixed. Generally, soil chemical characterizations of the studied soils before cultivation and directly after cereal crops harvesting as well as properties of the used matured co-compost and irrigation water were performed using classical methods as reported and explained by (Burt, 2004, Cottenie *et al.,* 1982) as tabulated in all Tables in this work. Ionic strength (mmoles L^{-1}): was calculated using the following equation as explained by (Tam, 1993).

Ionic strength (mmoles L^{-1}) = $\frac{1}{2} \sum_{i=1}^{i=n} M_i Z_i^2$

Where: M_i = conc. of ion (i) in mmoles L^{-1} and Z_i = charge of ion (i).

Additionally, undisturbed vertical cylindrical volumes of field-moist soil samples were gently obtained using cylindrical sharp edged core samplers for estimating soil physical properties and soil moisture constants using routine work analysis methods as reported and described by (Garcia, 1978, Klute, 1986) (Okalebo *et al.,* 1993, Reynolds, 1993a, Reynolds, 1993b). Soil moisture constants (field capacity, permanent wilting point and available water capacity) were measured and calculated by means of pressure cooker and pressure membrane apparatus for measuring moisture contents at pressures of 0.33 and 15 bar. Bulk and particle (real) densities were estimated. Soil porosity in volume percent was calculated. Field saturated hydraulic conductivity *in situ* was determined using constant head well permeameter method employing Guelph permeameter apparatus. All soil obtained values were calculated on oven dry weight basis 105 C ° for 24 hours. Soil physico-chemical analysis and moisture constants for the studied soil before cultivation are shown in Tables (1 and 2) respectively. Chemical properties of irrigation water under consideration during the carrying out are listed in Table (3). The experimental plot area was 6.0 m^2 (2x3 m). The experimental design was split-plot arrangement with three replications. The main plots were devoted to three irrigation treatments as follows: irrigation at 30,50 and 70 % depletion from soil available water capacity. Wheat and maize plants were exposed to deficit irrigation and started directly after life watering irrigation (El-Mohayaa irrigation) for achieving the selected available soil moisture depletion levels under consideration. Detailed experimental obtained data about irrigation scheduling and the actual seasonal applied water for wheat and maize crops production cultivated in loamy sand soils subjected to soil moisture depletion regimes over the growing winter and summer season periods are tabulated in Tables (6 and 7). The sub –plots were assigned to five types of soil conditioners and their mixtures 1:1:1(w/w). The conditioner treatments (w/w) were applied as follows: Control (without additions); Bentonite at application rate of 0.3%, compost at application rate of 0.5 %, polyacrylamide at application rate of 0.3 %; and the mixtures of the three previous conditioners in 1:1:1 ratio at rate of 0.37 %. The soil conditioner treatments were randomly distributed in the three main plots. The application rates of such conditioners were based on the recommended doses as described by (El-Naka *et al.,* 2015). They also detailed the physio-chemical analysis of PAM and bentonite. Meanwhile, the detailed analysis of compost had been done in Soil Improvement and Conservation Department, Sakha Agriculture Research Station.

Table (1): Initiative physico-chemical characteristics of the experimental site before planting

Soil characters and units	Values
Chemical analysis	
Soil reaction pH (1:2.5 soil-water suspension)	7.90
Electrical conductivity, Ec dSm^{-1} (soil past extract) at 25 Cº	2.75
Saturation percentage (S.P) %	40.0
Total soluble salts (T.S.S) *m*g kg^{-1} soil	1760
Calcium carbonate ($CaCO_3$) %	0.60
Total soluble ions (1:5 Soil-water extractions)	
Soluble cations	
Ca^{+2} *m*eq L^{-1}	1.00
Mg^{+2} *m*eq L^{-1}	1.20
Na^{+} *m*eq L^{-1}	3.70
K^{+} *m*eq L^{-1}	0.10
Soluble anions	
$CO_3^{=}$ *m*eq L^{-1}	0.00
HCO_3^{-} *m*eq L^{-1}	1.50
CL^{-} *m*eq L^{-1}	2.00
SO_4^{-2} *m*eq L^{-1}	2.50
Ec, dSm^{-1} (1:5 soil-water extraction)	0.602
Ionic strength (I.S) *mm*oles L^{-1}	4.45
Physical analysis	
Silt fraction %	31.0
Clay fraction %	13.5
Soil texture class	Loamy sand
Soil bulk density(Pb) Mg m^{-3}	1.55
Soil particle density (Ps) Mg m^{-3}	2.66
Total porosity(E) on volume basis %	41.73
Soil saturated hydraulic conductivity (S.H.C) *m* day^{-1}	2.65
Soil cation exchange capacity (CEC) cmolc/kg soil	15

Table (2): Soil moisture constants and its nutritional status of the experimental site before planting.

Soil variables	*Obtained values*
Soil moisture constants	
Field capacity (S.F.C) %	18.0
Permanent wilting point (P.W.P) %	9.00
Available water capacity (A.W.C) %	9.00
Soil nutritional status	
Total organic-C %	0.232
Organic matter (O.M) %	0.400
Available macro-nutrients	
Available – N (K-sulphate extractable) *mgkg*$^{-1}$ soil	21.5
Available – P ($NaHCO_3$ extractable) *m*gkg^{-1} soil	8.90
Available – K (NH_4-acetate extractable) *m*gkg^{-1} soil	53.5
Available micronutrients	
Available – Fe(DTPA extractable) *m*gkg^{-1} soil	6.50
Available - Mn(DTPA extractable) *m*gkg^{-1} soil	5.00
Available-Zn(DTPA extractable) *m*gkg^{-1} soil	1.10
Available – Cu (DTPA extractable) *m*gkg^{-1} soil	0.66

Table (3): Chemical analysis of irrigation water under consideration during the carrying out of field experimental periods.

Irrigation water source	*pH*	*Ec dS m^{-1}*	*Total soluble cations meq L^{-1}*					*Sodium hazard parameters*		*Total soluble anions meq L^{-1}*					*Ionic strength mmol L^{-1}*
			Ca^{++}	Mg^{++}	Na^{+}	K^{+}	Σ Cations	SAR	SSP %	$CO_3^{=}$	HCO_3^{-}	Cl^{-}	$SO_4^{=}$	Σ Anions	
El-Gharbia main drain (Cotchner) (at Abou Omera east village, Baltim district)	7.94	1.52	3.5	2.3	9.2	0.15	15.15	5.76	60.73	0.0	5.1	7.1	3.0	15.2	18.075

These conditioner types are mixed well with soil and incorporated into soil surface before plowing during soil service process and its preparation before planting. The chemical analysis of these conditioners is listed in Tables (4,5 and 6) for bentonite, compost and polyacrylamide respectively. Seeds of wheat plants (*Triticum aestivum*, Misr1 variety) were obtained from Crop Agronomy Research Department, Sakha Agriculture Research Station and sown on November11,2015. Grains of maize plants (*Zea mays, L*) three cross 321 variety were obtained from Maize Research Center, Agriculture Research Center and sown on May,15,2016. Aerobic / Thermophilic co-composting process was carried out at the experimental farm of Soil Improvement and Conservation Research Department, Sakha Agriculture Research Station before beginning of the winter growing season elongated five months from May 2015 to October 2015. Pyramidical piles (heaps) 2.5 × 2.5 ×1.5 m was built up under aerobic conditions. Different solid bio-wastes were used as substrates and augmented organically with farmyard manure (10 % w/w) as microbial organic activator as well as with urea, super phosphate and potassium sulfate as microbial chemical activators. The other certain additional materials were incorporated into for speeding up the conversion and improving the final product quality and as growth promoting substances, pH buffering agents and as bulking agents. The obtained chemical and physical characteristics of the used matured co-compost after co- composting process are listed in Table (5). This matured co-compost was used as soil conditioner.

1.1. Irrigation water supply and calculations:

Irrigation water supply and number of irrigations were limited per the levels of soil moisture depletion regimes. Consequently, soil moisture content at demand depletion levels determines the timing of irrigation. Soil moisture content directly before irrigation at which calculated applied water must be added immediately for arriving at soil field capacity was measured in *situ* using TDR apparatus (Time Domain Reflectometer). The magnitude of planting and life watering irrigates were measured and applied using cutthroat flume(20 ×90 cm)according to (Early, 1975). Magnitude of irrigation applied water were calculated using the following soil moisture depletion equation as reported by (Israelson and Hansen, 1962) during wheat and maize growing season periods.

$$Q = \frac{SFC - CMC}{100} \times Bd \times D \times A$$

Where: Q = Quantity of applied water m^3 $plot^{-1}$ /irrigate; SFC = Soil field capacity (%) in percent by volume; CMC = Soil moisture content just before irrigation using TDR apparatus; Bd = Soil bulk density Mg m^{-3} ; D = Soil depth (m), effective root depth or soil depth required to be irrigated; and A = plot experimental area (m^2) that would be irrigated.

Total irrigation water applied for wheat and maize crops subjected to the required irrigation regime is detailed in Tables (7&8). Water productivity was calculated as the weight of marketable crop production per the volume unit of applied irrigation where expressed as cubic meter of water.

Wheat crop was harvested on 25 from March, while maize crop was harvested on 30 of August.

Table (4): Chemical and mineralogical analysis of the used bentonite.

Characteristics	*Values*
Elemental oxides: %	
SiO_2	55.9
TiO_2	0.20
Al_2O_3	20.0
Fe_2O_3	0.70
MnO	0.001
MgO	0.65
CaO	2.70
Na_2O	1.76
K_2O	2.40
P_2O_5	0.80
SO_3	-
Loss on ignition	10.0
Ec_e dS m^{-1}(1:10 Bentonite-water extract(w/v)	1.82
pH (1:2.5 bentonite-water suspension (w/v)	7.12
Total soluble cations (*m*eq L^{-1}) (1:5 extracts)	
Ca^{+2}	0.79
Mg^{+2}	0.27
Na^{+}	1.95
K^{+}	0.02
Total soluble anions (*m*eq L^{-1}) (1:5 extracts)	
$CO_3^{=}$	-
HCO_3^{-}	0.24
Cl^{-}	1.59
$SO_4^{=}$	1.06
Cation exchange capacity, cmoles kg^{-1}	59.13
Calcium carbonate %	14.27
Particle size distribution %	
Clay fraction	85.75
Silt fraction	10.54
Sand fraction	3.71

Table (5): The detailed analysis of the used compost

Characteristics	*Values*
Dry weight (kg m^{-3})	650.0
Moisture content (%)	25.5
Odor and color	Acceptable and dark
pH (1:10 compost-water suspension w/v)	7.16
EC (1:10 compost – water extraction w/v)	5.23
Total soluble salts (soil paste –water extraction 1:10) %	0.335
Saturation percentage % (g/100g	175.0
Total soluble salts (compost material) % (g/100g compost)	0.586
CEC (cmole kg^{-1})	64.34
Total organic – c %	25.5
Total organic matter %	43.96
C/N ratio	21.98
Total macro-nutrients %	
Total – nitrogen %	1.16
Total – phosphorus %	0.53
Total – potassium %	0.37
Available macro-nutrients (*m*g kg compost)	
Available – N (potassium sulfate)	100
Available – P (0.5 M $NaHCO_3$- pH 8.5)	50
Available – K (ammonium acetate pH 7)	85
Available micro-nutrients (*m*g kg compost)	
Available – Fe	450
Available – Mn	100
Available – Zn	35
Available – Cu	135
Total micro-nutrients (*m*g kg compost)	
Total –Fe	753
Total – Mn	361
Total – Zn	297
Total – Cu	168
Available heavy metals (*m*g kg compost)	
Available – Cd	13.2
Available – Ni	62.7
Available – Pb	120

Table (6): Physicochemical properties of the anionic polyacrylamide (PAM).

Characteristics	Values
Viscosimetry molecular weight (g/mol)	104758.9
pH	7.4
Total carbon (%)	42.2
Total nitrogen (%)	16.2
C/N	2.6
Molar volume (mL mol^{-1}	54.6
Density (g cm^{-3})	1.2
Molecular weight (g mol^{-1})	71.08
Van-der-Waals volume (ml mol^{-1})	38.6
Water solubility	Soluble
Melting point	>300 °C
Retention	High retention rate
Toxicity	Non-toxic

Table 7

Table 8

1.2. Statistical analysis:

Analysis of variance was done according to (Snedecer and Cochran, 1976) using the Irristat software, version 4.1 according to Biometrics Unit,1998, (IRRI, 1998).

RESULTS AND DISCUSSION

1.3. Soil chemical properties in response to adding soil conditioners

Concerning the effect of applying natural soil conditioner types and their mixtures (1:1:1) in loamy sand soils subjected to soil moisture depletion regimes (30%, 50 % and 70 %) from their available water capacities after wheat and maize crops harvesting on soil salinity pH, EC (dS m^{-1}), and ionic strength mmole L^{-1} and hazard sodium parameters (SAR and SSP %) are listed in Tables (9.1 and 9.2). Generally, the analytical chemicals results listed in after mentioned tables illustrate that values of these chemical parameters in the studied soil on the average of other studied parameters (irrigation treatments) were markedly increased due to the application of soil conditioner types in comparison with control values (without additions). These increases could be arranged in the following descending order as follow: mixtures (1:1:1) > polyacrylamide> bentonite > compost > control**.** The highest values were achieved because of mixtures application, meanwhile, the lowest values were obtained by dressing the compost treatment. Increasing the values of chemical parameters for soil after conditioner applications is mainly attributed to the initial analysis of these conditioners.

On the other hand, these studied chemical properties, on the average of the other studied parameters (conditioner types), were markedly increased with increasing the depletion regimes from its soil available water capacity. Where, the highest values of these chemical parameters were achieved under dry treatment (70 % AWSMD), meanwhile, the lowest values were recorded under wet treatment (30 % AWSMD). Medium treatment had the moderate values between wet and dry treatments. The analytical obtained increments could be rearranged in the following ascending order: wet –treatment (30 % AWSMD) < medium – treatment (50 % AWSMD) < dry – treatment (70 % AWSMD). This could be attributed to the dilution effect, since, salt concentration was decreased with increasing irrigation applied water. Data listed in Table (9.2) reveal also that under maize experiment, the studied chemical properties were increased with adding soil conditioner types and their mixtures (1:1:1) on the overall average of the other studied parameters (irrigation treatments) in comparison with their control –values (without additions) at the same conditions. These parameters mannered the following descending order: mixtures (1:1:1) > polyacrylamide > bentonite > compost > control. Generally, the obtained values of chemical properties after wheat crop harvesting were lower than those obtained after maize crop harvesting. This mainly attributed to residual effects of conditioners remained from winter season as a doubling effect with the new added doses in summer season.

1.4. Soil physical properties:

The results collected in Tables (10.1&10.2) show that, on average of other studied parameters (irrigation treatments), that saturated hydraulic conductivity SHC (m day^{-1}) and bulk density Db (Mg m^{-3}) were markedly decreased as a result of adding soil conditioner types and their mixtures (1:1:1) in the studied soil after wheat crop harvesting in comparison with their control values. The magnitude of these decrements which less the control values were depended upon the types of these conditioners. It is clearly that; the lowest values were achieved and accompanied with applying polyacrylamid treatment. Meanwhile, the highest values were obtained with the dressing compost conditioner in comparison with their control values. These decrements could be arranged in the following descending order as follows: polyacrylamide > mix of all > bentonite >

Table 9

Table (10.1): Saturated hydraulic conductivity, bulk density and total porosity of studied soils after wheat crop harvesting as affected by natural soil conditioner types and their mixtures under different soil moisture depletion regimes.

Soil conditioner types and their mixtures	Soil moisture depletion levels from its available water capacity (AWSMD-levels)								
	Wet - treatment (30 % AWSMD)			Medium - treatment (50 % AWSMD)			Dry -treatment (70 % AWSMD)		
	SHC (m/day)	D_b (Mg /m^3)	ρ_T (%)	SHC (m/day)	D_b (Mg /m^3)	ρ_T (%)	SHC (m/day)	D_b (Mg /m^3)	ρ_T (%)
Control	2.48	1.55	41.51	2.54	1.56	41.13	2.47	1.57	40.7
Bentonite	2.41	1.45	45.28	2.40	1.41	46.79	2.43	1.40	47.17
Compost	2.43	1.45	45.28	2.43	1.42	46.42	2.53	1.30	50.94
Polyacrylamide	2.32	1.34	49.43	2.34	1.31	50.57	2.39	1.32	50.19
Mix of all (1:1:1)	2.38	1.43	46.00	2.36	1.40	47.17	2.37	1.35	49.06

Table (10.2): Saturated hydraulic conductivity, bulk density and total porosity of studied soils after maize crop harvesting as affected by natural soil conditioner types and their mixtures under different soil moisture depletion regimes.

Soil conditioner types and their mixtures	Soil moisture depletion levels from its available water capacity (AWSMD-levels)								
	Wet - treatment (30 % AWSMD)			Medium - treatment (50 % AWSMD)			Dry -treatment (70 % AWSMD)		
	SHC (m/day)	D_b (Mg/m^3)	ρ_T (%)	SHC (m/day)	D_b (Mg /m^3)	ρ_T (%)	SHC (m/day)	D_b (Mg /m^3)	ρ_T (%)
Control	2.63	1.50	43.40	2.60	1.48	44.15	2.55	1.52	42.64
Bentonite	2.32	1.34	49.80	2.31	1.30	50.94	2.40	1.22	53.96
Compost	2.42	1.35	49.06	2.32	1.30	50.94	3.17	1.28	51.70
Polyacrylamide	2.20	1.32	49.43	2.48	1.40	47.17	3.10	1.30	50.94
Mix of all (1:1:1)	2.34	1.33	48.30	2.35	1.35	49.06	2.00	1.32	50.19

Table 9 compost > control. Oppositely, soil porosity values were mannered the opposite trend, where such values were increased over the control –values with adding soil conditioners and had the following sequence: polyacrylamide < mix of all < bentonite < compost < control. On the other hand, it was clearly apparent that, SHC values were gradually increased with increasing water irrigation deficits. However, Db and ρ_T had the opposite trend, which decreased with increasing soil moisture depletion levels for its available water capacity. SHC – increments as well as Db and ρ_T decrements with increasing moisture depletion levels could be arranged in the following descending order as follows: wet – treatment (30% AWSMD) > medium – treatment (50% AWSMD) > dry – treatment (70% AWSMD).

1.5. Soil moisture constants:

As concerns, field capacity (SFC %), permanent wilting (PWP %) and available water capacity (AWC%) values of the studied loamy sand soils which reflect their soil water holding capacity after wheat and maize crops harvesting as affected by soil conditioner types and their mixtures under soil moisture depletion regimes, are presented in Tables (11.1 and 11.2) respectively. The obtained results, demonstrate that, on average of the other studied parameters (irrigation treatments), these soil moisture constants were obviously increased by applying soil conditioners and their mixtures (1:1:1) in comparison with their control values at the same conditions. Generally, these increments over the controls in studied soil after wheat crop harvesting could be arranged in the following sequence as follows: polyacrylamide > mix of all >bentonite > compost > control**.** Soil water holding capacity parameters in summer season were higher than those in winter season, due to the residual effects of conditioners remained from winter season. Where the conditioners were added twice, the first time was before wheat cultivation and the second application was before maize cultivation with the same rates and in the same field as well**.** Analytical results show that application of polyacrylamide show its superiority over all other conditioner types under wheat and maize experiments**.** This is because, it is highly water-absorbent, forming a soft gel when hydrated. This function gives this conditioner the capacity to hold much water as compared with other soil conditioners.

Table (11.1): Field capacity, permanent wilting point and available water capacity of studied soils after wheat crop harvesting as affected by natural soil conditioner types and their mixtures under different soil moisture depletion regimes.

Soil conditioner types and their mixtures	Soil moisture depletion levels from its available water capacity (AWSMD-levels)								
	Wet- treatment (30 % AWSMD)			Medium - treatment (50 % AWSMD)			Dry - treatment (70 % AWSMD)		
	SFC (%)	PWP (%)	AWC (%)	SFC (%)	PWP (%)	AWC (%)	SFC (%)	PWP (%)	AWC (%)
Control	18.0	9.0	9.0	17.8	9.2	8.6	17.9	8.8	9.1
Bentonite	18.9	9.5	9.4	18.8	9.6	9.2	19.8	9.2	10.6
Compost	18.7	9.4	9.3	18.3	9.4	8.9	19.5	9.0	10.5
Polyacrylamide	19.7	10.0	9.7	20.3	10.4	9.9	20.5	10.3	10.2
Mix of all (1:1:1)	19.5	9.8	9.7	19.7	10.0	9.7	20.2	10.2	10.0

Table (11.2): Field capacity, permanent wilting point and available water capacity of studied soils after maize crop harvesting as affected by natural soil conditioner types and their mixtures under different soil moisture depletion regimes.

Soil conditioner types and their mixtures	Soil moisture depletion levels from its available water capacity (AWSMD-levels)								
	Wet- treatment (30 % AWSMD)			Medium - treatment (50 % AWSMD)			Dry - treatment (70 % AWSMD)		
	SFC%	PWP %	AWC %	SFC%	PWP %	AWC%	SFC%	PWP %	AWC%
Control	17.0	8.5	8.5	16.6	8.2	8.4	16.4	8.2	8.2
Bentonite	18.4	9.0	9.4	17.8	8.8	9.0	17.3	8.5	8.8
Compost	18.1	8.8	9.3	18.5	8.9	9.6	17.5	8.8	8.7
Polyacrylamide	20.4	10.0	10.4	19.4	9.7	9.7	19.0	9.4	9.6
Mix of all (1:1:1)	19.5	9.8	9.7	18.7	9.3	9.4	18.2	9.0	9.2

1.6. Grain and straw yield of wheat and maize crops:

Data listed in Tables (12.1, 12.2 and 12.3) demonstrate, on average other studied parameters (irrigation treatments), that application of soil conditioner types and their mixtures (1:1:1) resulted in significantly increasing wheat and maize grain yield, thousand grains weight, harvesting index and straw yield in comparison with their control values at the same conditions. The increments of these agronomical traits could be arranged in the following descending order as: polyacrylamide> mixtures (1:1:1) > bentonite > compost > control. This mainly due to the ability of PAM in holding water rather than other conditioners. Where the retention properties of PAM are better than those in other types of conditioners. So, the highest values of these agronomical features in studied sandy soils were achieved and accompanied by applying conditioner – PAM treatment under both crops. However, the analytical obtained data, on average of the other studied parameters (conditioner treatments) reveal that all agronomical features except for harvest index were gradually decreased with increasing soil moisture depletion levels from its available water capacity. The magnitude of these decrements could be arranged in the following descending order as: wet-treatment (30% AWSMD) > medium –treatment (50% AWSMD) > dry –treatment (70 % AWSMD). However, harvest index (%) was slightly increased with increasing irrigation deficits. Therefore, these increments could be arranged in the following sequence as: dry –treatment (70 % AWSMD) > medium –treatment (50% AWSMD) > wet-treatment (30% AWSMD).

Generally, mean values of these parameters under medium treatment were higher than those obtained under wet and dry treatments and behaved the following order: medium > wet > dry. Such results were obtained by (Abdel-Rheem and Hassan, 2011) **,** they found that the highest values of wheat water productivity and yield were achieved when irrigation at 50 % depletion from available water , compared to 70 % and 40 % depletion in the loamy soils. confirming this conclusion, similar responses of maize crop production under field conditions was also reported by (Khalifa, 2013) who stated that, irrigation at 50 % SMD gave the highest values of yield and its components of maize crop.

Table (12.1): Grains and straw yields of wheat and maize crops after full maturity as affected by natural soil conditioner types and their mixtures under 30 % SMD.

Soil conditioner types and their mixtures	Wheat crop yield				Maize crop yield			
	Grains yield (kg fed^{-1})	1000 grains weight (gm)	HI (%)	Straw yield (kg fed^{-1})	Grains yield (kg fed^{-1})	100 grains weight (gm)	HI (%)	Straw yield (kg fed^{-1})
Control	1276.5	30.5	30.75	2875	1820	40.6	47	2053
Bentonite	1749.8	40.65	37.25	2953	2875	43.45	49.19	2970
Compost	1600.5	40.35	35.61	2888	2728	42.65	48.45	2903
Polyacrylamide	2218.6	45.35	39.47	3403	2946	44.85	44.77	3635
Mix of all (1:1:1)	2020.6	43.05	39.26	3115	2926	44.10	45.94	3444

Table (12.2): Grains and straw yields of wheat and maize crops after full maturity as affected by natural soil conditioner types and their mixtures under 50 % SMD.

Soil conditioner types and their mixtures	Wheat crop yield				Maize crop yield			
	Grains yield (kg fed^{-1})	1000 grains weight (gm)	HI (%)	Straw yield (kg fed^{-1})	Grains yield (kg fed^{-1})	100 grains weight (gm)	HI (%)	Straw yield (kg fed^{-1})
Control	1302	30.6	32.69	2680	1977	41.2	42.46	2676
Bentonite	1732.5	40.4	37.07	2935	2945	44.2	47.14	3318
Compost	1578	40.1	35.82	2823	2846	43.05	49.19	2940
Polyacrylamide	2017.5	44.4	39.77	3055	3051	43.7	44.26	3827
Mix of all (1:1:1)	1950	42.5	39.57	2969	3037	44.75	44.86	3776

Table (12.3): Grains and straw yields of wheat and maize crops after full maturity as affected by natural soil conditioner types and their mixtures under 70 % SMD.

Soil conditioner types and their mixtures	Wheat crop yield				Maize crop yield			
	Grains yield (kg fed^{-1})	1000 grains weight (gm)	HI (%)	Straw yield (kg fed^{-1})	Grains yield (kg fed^{-1})	100 grains weight (gm)	HI (%)	Straw yield (kg fed^{-1})
Control	1000	30.3	34.45	1903	1900	40.0	49.22	1960
Bentonite	1458	39.8	37.72	2408	2795	42.73	49.16	2893
Compost	1306	39.5	35.47	2376	2625	41.55	48.89	2744
Polyacrylamide	1847	43.7	44.23	2330	2870	41.90	43.25	47.21
Mix of all (1:1:1)	1697	43.4	38.02	2298	2841	41.74	45.42	3421

Regarding the statistical analysis of soil conditioners on wheat and maize grain yield, data in Table (13) showed that, there are highly significant differences between polyacrylamide and bentonite and between compost and control in increasing the wheat grain yield. Significant differences also were noticed between mix of all and bentonite. Meanwhile, in case of maize crop, it was noticed that, the high significant effects were noticed between different conditioners and control. But there are no significant differences between conditioners themselves. This may be attributed to the residual effect of conditioners that already remained in soil from the previous wheat season.

Respecting deficit irrigation and its effect on wheat and maize grain yield, it was noticed that there are no significant impacts of deficit irrigation on wheat. However, a significant impact was recorded under maize yield. This is may be due to increasing temperature in summer season and hence its effect on increasing evapotranspiration in comparison with winter season. But generally, there are no significant differences between (D1,30%) and (D2,50%) under both crops. Consequently, applying deficit irrigation to 50 % depletion from available water could achieve the same higher yield and save much water in loamy sand soils. These results agree with those obtained by (Husman *et al.,* 2000)**.** They found that wheat grain yield, harvest index and water use efficiency were greater when irrigation was applied at 50% soil moisture depletion and was reduced at 70% depletion.

Table (13): Statistical analysis of the grain yield of wheat and maize under applying different conditioners and different levels of water depletion.

Wheat		Maize	
Conditioners	Grain yield (Ardeb/fed)	Conditioners	Grain yield (Ardeb/fed)
Control	7.957	Control	13.5
Bentocide	12.102	Bentocide	20.5
Compost	10.865	Compost	19.5
Polyacrylamide	14.744	Polyacrylamide	20.9
Mix of all	13.937	Mix of all	20.8
F-test	**	F-test	**
L.S.D 0.05	1.5948	L.S.D 0.05	1.7
L.S.D 0.01	2.1475	L.S.D 0.01	2.2
30 %	12.399	30 %	19.9
50 %	12.212	50 %	19.8
70 %	11.152	70 %	18.5
F-test	ns	F-test	*
L.S.D 0.05	1.235	L.S.D 0.05	1.1
L.S.D 0.01	1.663	L.S.D 0.01	1.4

1.7. Crop water productivity:

Data in Fig.1 (A) showed that wheat water productivity values increased significantly as affected by application of natural soil conditioners. Under irrigation at 30% depletion from available water, the highest values of WP were recorded 1.7 kg m^{-3} with treatment polyacrylamide followed by 1.67, 1.6 and 1.45 kg m^{-3} for mix of all, bentonite and compost respectively compared to control 1.03 kg m^{-3}. Data also indicated that, values of WP increased under irrigation at 50% depletion from available water and gave average values 1.53 kg m^{-3} as compared to irrigation at 30% and 70% depletion from available water. At this irrigation regime, the highest values of WP, 1.9 kg m^{-3} was recorded with adding polyacrylamide followed by 1.83, 1.61 and 1.45 for mix of all, bentonite and compost, respectively as compared to 1.13 kg $m^{-3}$with control. On the other hand, irrigation at 70% depletion from available water gave the lowest values of WP as compared to irrigation at 30 and 50%. This may be due to decreasing grain yield in this irrigation regime as compared to others. Regarding maize crop water productivity as affected by different treatments, Data in Fig. 1 (B) shows that maize water productivity increased with applying conditioners. Where, under 30 % depletion, maize water productivity increased to 1.7, 1.7, 1.5 and 1.3 kg m^{-3} for polyacrylamide, mix of all, bentonite and compost respectively as compared with control 1.0 kg m^{-3}. With respect to irrigation depletion and its effect on maize water productivity. Data show that, under the same conditioner, mean value of water productivity under 50 % depletion was 1.54 kg m^{-3}which decreased to 1.39 kg m^{-3}under 70 % depletion passing by 1.44 kg m^{-3}under 50 % depletion from available water. These results were in accordance with those obtained by (Saleh and Ozawa, 2006) and (Karrou *et al.,* 2012).

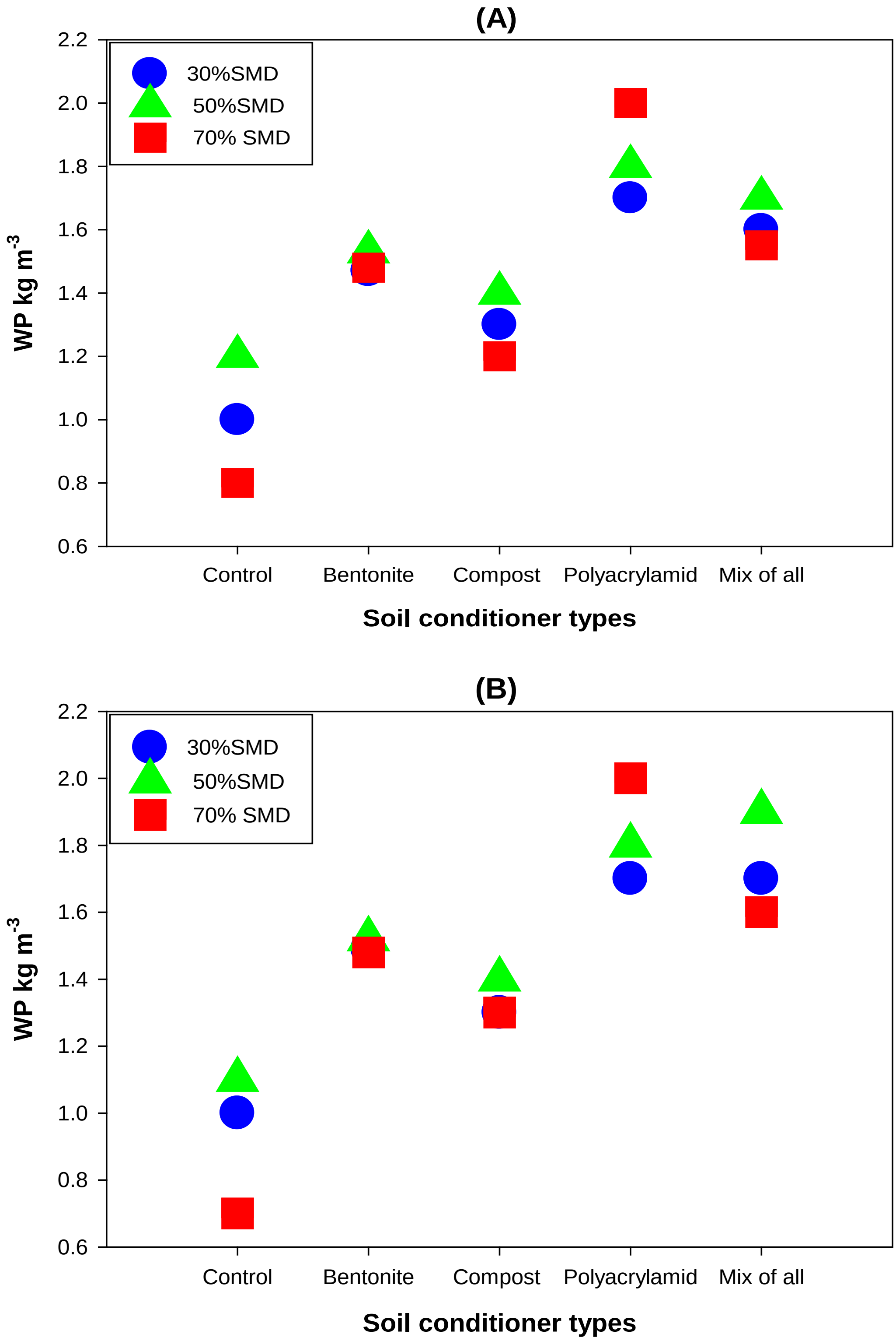

Fig.1. Crop water productivity for wheat (A) and maize (B) subjected to soil conditioners and irrigation regime.

In conclusion, we can deduct that irrigation regime of 50 % depletion from available water which achieved higher values of water productivity saved about 85.7 and 313.2 $m^3 fed^{-1}$ for both wheat and maize crops respectively (Tables 7 and 8). Also, polyacrylamide and mix of all conditioners are considered the best conditioners improved soil properties, and crop water productivity under sandy soil conditions.

Conclusion:

Sandy soils hold little water as the large pore spaces allow water to drain freely from soil. The productivity of these soils is limited by low water holding capacities, high infiltration rates, high evaporation, low inherent fertility levels, very low organic matter content and excessive deep percolation losses. Also, the water use efficiency of the crops cultivated in such soil is low. Therefore, the study was conducted in winter and summer seasons for the main strategic crops (wheat and maize) using different types of soil conditioners under sandy soil conditions. Also, to explore the water use efficiency of both crops under different conditioners, different irrigation regimes as deficit irrigation from available water were used. Conventional conditioner like compost and unconventional conditioners (e.g. bentonite, polyacrylamide and mix of all) were used to explore the outcome variability for each type. The study concluded that polyacrylamide achieved the highest values of crop yield and crop water productivity in response to improving soil physical and chemical properties. Irrigation at 50 % depletion from available water recorded the highest yield and water productivity and saved much water in comparison with 30 and 70 %.

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دراسه فاعليه محسنات التربه والنظام الرطوبي علي :
1- خواص الاراضي اللوميه الرمليه وانتاجيه المحاصيل وكذلك انتاجيه وحده المياه

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الملخص العربى

اقيمت تجربتان حقليتان بالاراضي اللوميه الرمليه في مركز بلطيم - كفرالشيخ لزراعه محصولي القمح والذره في موسمين 2015 /2016 و 2016 للشتوي والصيفي علي الترتيب. وكانت الاهداف الرئيسيه لهذه الدراسه هو تقييم ودراسه تأثير انواع مختلفه من محسنات التربه ومخاليطها تحت ظروف نظم رطوبه ارضيه مختلفه علي :1- خواص الاراضي الرمليه سواء الطبيعيه او الكيميائيه بعد الحصاد ، 2- انتاجيه الاراضي الرمليه من محاصيل الحبوب الرئيسيه (القمح والذره) وكذلك انتاجيه وحده المياه من تلك المحاصيل.

لذا تم استخدام اربعه انواع من المحسنات الارضيه وهي (خام البنتونيت ، الكمبوست ، البولي اكريلاميد وكذا مخاليط من الثلاثه بنسبه 1:1:1 (وزنا). تم اضافه هذه المحسنات للتربه قبل الزراعه. ايضا تم تطبيق ثلاثه معاملات للري علي اساس استنفاذ الرطوبه الارضيه من الماء الميسر وهي (30 % ، 50 % ، 70 %).

اوضحت النتائج ان اضافه محسنات التربه المختلفه ادي الي تحسين خواص الاراضي الرمليه سواء الكيميائيه او الطبيعيه وكذا احتفاظ التربه بالماء. حيث ان هذه المحستاب ادت لزياده ملوحه التربه ، والصوديوم والمساميه الكليه. بينما انخفضت قيم الكثافه الظاهريه والتوصيل الهيدروليكي نتيجه لاضافه هذه المحسنات. ولتحديد افضل نوع من هذه المحسنات فقد لوحظ ان البولي اكريلاميد اعطي افضل النتائج يليه المخلوط الشامل. ومن وجهه النظر المائيه فان الري عند استنفاذ 50 % من الماء الميسر اعطي افضل القيم لكلا من انتاجيه المحاصيل وكذا انتاجيه وحده المياه من هذه المحاصيل. وبصفه عامه فان هذه المحسنات ادت لزياده انتاجيه محاصيل الحبوب ، البروتين، ووزن الحبوب وكذلك مكونات المحصول الاخري.

Table (7): Irrigation scheduling and actual seasonal applied water for wheat crop production cultivated in loamy sand soil under different soil moisture depletion regimes over the growing winter season period 2015/2016.

Irrigation scheduling	Soil moisture depletion								
	30 % AWSMD			50 % AWSMD			70 % AWSMD		
	Irrigation date	Applied water		Irrigation date	Applied water		Irrigation date	Applied water	
		L $plot^{-1}$	$m^3 fed^{-1}$		L $plot^{-1}$	$m^3 fed^{-1}$		L $plot^{-1}$	$m^3 fed^{-1}$
Planting irrigation (7.63 %SMC)	20/11/2015	130	91.4	20/11/2015	130	91.4	20/11/2015	130	91.4
Life watering irrigation (12.31 % SMC)	30/11/2015	65.2	45.7	30/11/2015	65.2	45.7	30/11/2015	65.2	45.7
Summation		195.2	137.1	Summation	195.2	137.1	Summation	195.2	137.1
Soil moisture content %	15.33 %SMC			13.5 % SMC			11.7 % SMC		
Regular- intervals	Short-intervals Every 3 days			Median-intervals Every 5 days			Long- intervals Every 7 days		
First irrigate	3/12/2015	40.8	25.22	5/12/2015	68.0	42.028	7/12/2015	95.2	58.85
Final irrigate	9/3/2016	40.8	25.22	6/3/2016	68.0	42.028	2/3/2016	95.2	58.85
Number of irrigates	33 irrigates plus planting and life watering irrigations			18 irrigates plus planting and life watering irrigations			12 irrigates plus planting and life watering irrigations		
Calculated applied water /season		1346.4	942.5		1224	856.8		1142.4	799.7
Precipitation / season		300.00	210.0		300.0	210.0		300.0	210.0
Total applied water /season		1541.6	6474.7		1419.2	993.4		1337.6	936.3
Actual seasonal applied water		1841.6	1289.12		1719.2	1203.4		1637.6	1146.3

Notes: 1- Total applied water/season = calculated applied water +planting and life watering irrigations.
2- Actual seasonal applied water = total applied water / season + total precipitation/season.

Table (8): Irrigation scheduling and actual seasonal applied water for maize crop production cultivated in loamy sand soil under different soil moisture depletion regimes over the growing summer season 2016.

Irrigation scheduling	Soil moisture depletion								
	30 % AWSMD			50 % AWSMD			70 % AWSMD		
	Irrigation date	Applied water		Irrigation date	Applied water		Irrigation date	Applied water	
		$Lplot^{-1}$	m^3fed^{-1}		$Lplot^{-1}$	m^3fed^{-1}		$Lplot^{-1}$	m^3fed^{-1}
Planting irrigation (6.48 % SMC)	15/5/2016	321.3	224.9	15/5/2016	321.3	224.9	15/5/2016	321.3	224.9
Life watering irrigation (9.75 % SMC)	20/5/2016	230.1	161.0	20/5/2016	230.1	161.0	20/5/2016	230.1	161.0
Summation		551.4	385.9	Summation	551.4	385.9	Summation	551.4	385.9
Soil moisture content %	15.33 %SMC			13.5 % SMC			11.7 % SMC		
Regular- intervals	Short- intervals (every day)			Median- intervals (3 days)			Long- intervals (5 days)		
First irrigate	23/5/2016	75.3	52.73	25/5/2016	200	140	28/5/2016	326.4	228.5
Final irrigate	15/8/2016	75.3	52.73	12/8/2016	200	140	10/8/2016	326.4	228.5
Number of irrigates	75irrigates plus planting and life watering irrigations			26 irrigates plus planting and life watering irrigations			15 irrigates plus planting and life watering irrigations		
Calculated applied water /season		5647.5	3953.3		5200	3640		4896.4	3427.5
Total applied water /season		6198.9	4339.2		5751	4026		5447.8	3813.4

Notes: Amounts of applied water for planting and life watering irrigations (L $plot^{-1}$/irrigate) were measured using cutthroat flume (20×90).

Table (9.1): Chemical properties of loamy sand soil after wheat crop harvesting as affected by natural soil conditioner types and their mixtures under different soil moisture depletion regimes.

Soil conditioner types and their mixtures	Soil moisture depletion levels from its available water capacity (AWSM D-levels)														
	Wet- treatment (30 % AWSMD)					Medium - treatment (50 % AWSMD)					Dry-treatment (70 % AWSMD)				
	pH	EC dSm^{-1}	H.S. parameters		I.S *m*mol L^{-1}	pH	EC dSm^{-1}	H.S. parameters		I.S *m*mol L^{-1}	pH	EC dSm^{-1}	H.S. parameters		I.S *m*mol L^{-1}
			SAR	SSP %				SAR	SSP %				SAR	SSP %	
Control	7.84	0.35	2.69	64.52	3.58	7.64	0.38	2.58	62.50	4.46	7.42	0.46	2.17	54.05	5.35
Bentonite	8.24	0.68	3.90	64.52	7.96	8.50	0.70	4.91	71.68	9.37	8.14	0.97	4.85	62.00	10.05
Compost	8.19	0.69	4.20	62.63	8.36	8.19	0.61	4.56	58.80	8.58	8.50	0.90	4.72	60.81	9.68
polyacrylamide	8.16	0.97	4.32	62.50	12.45	8.28	0.75	4.66	67.56	11.36	8.50	0.94	4.66	64.44	11.40
Mix of all (1:1:1)	8.35	1.50	6.99	69.57	12.66	8.39	1.90	5.92	67.77	12.54	8.60	1.17	5.45	67.33	14.24

Table (9.2): Chemical properties of loamy sand soil after maize crop harvesting as affected by natural soil conditioner types and their mixtures under different soil moisture depletion regimes

Soil conditioner types and their mixtures	Soil moisture depletion levels from its available water capacity (AWSM D-levels)														
	Wet- treatment (30 % AWSMD)					Medium - treatment (50 % AWSMD)					Dry-treatment (70 % AWSMD)				
	pH	EC dSm^{-1}	H.S. parameters		I.S *m*mol L^{-1}	pH	EC dSm^{-1}	H.S. parameters		I.S *m*mol L^{-1}	pH	EC dSm^{-1}	H.S. parameters		I.S *m*mol L^{-1}
			SAR	SSP %				SAR	SSP %				SAR	SSP %	
Control	7.80	0.32	2.86	64.71	3.64	7.60	0.35	2.86	63.36	4.45	7.40	0.44	3.26	63.13	5.36
Bentonite	8.20	0.68	4.20	64.79	8.87	8.16	0.67	4.04	63.01	9.64	8.14	0.87	4.32	63.41	10.12
Compost	8.10	0.69	4.61	63.51	8.52	8.15	0.72	3.71	58.97	9.05	8.30	0.87	4.59	63.44	9.52
polyacrylamide	8.21	0.97	4.63	62.38	12.67	8.18	0.74	4.24	63.29	13.28	8.40	0.94	4.77	63.37	14.72
Mix of all (1:1:1)	8.15	1.13	4.29	63.64	13.36	8.20	1.12	5.17	63.33	14.95	8.22	1.07	5.09	63.48	15.28