INCREASING SOIL STRUCTURE STABILIZATION WITH CARBOXYLIC POLYECTROLYTE

Mihai CARA[1], Irina COROI[1], Gerard JITAREANU[1]

e-mail: caramihai2005@yahoo.com

Abstract
Plants growth and development, water and soil solution are highly connected to its physical properties. Application of synthetic polymers as soil conditioners improves soil physical properties which increase soil resistance against disruptive forces and erosion. The objective of this study was to establish the direct effect of carboxylic polyelectrolyte *"Ponilit GT1*" on soil structure and indirectly on some physical properties, bulk density, total porosity and penetration resistance. The researches have been conducted at the Didactical and Experimental Research Station Ezareni belonging to ''Ion Ionescu de la Brad'' University of Agriculture Sciences and Veterinary Medicine Iasi, Romania. A randomized complete block design with three replications was used in the experiment. Carboxylic polyelectrolyte *"Ponilit GT1"* was applied at 0.1% and 0.3% concentrations. Soil structure development was evaluated by comparing the structural parameters treated with those untreated with carboxylic polyelectrolyte. The result of this study shows increased values of studied parameters after application of carboxylic polyelectrolyte within sowing-emergence period and only 0-5 cm depth. Because the thickness of the soil treated with polymeric substances is small, the values of studied parameters in 12-15 cm depth and 22-27 cm respectively, are not significantly different remaining within limits close to control.

Key words: Polymers, structure, bulk density.

Maintenance and improvement of soil fertility are imperative to meet the increasing demand for food in the word (Tumsavas et al., 2011). An agricultural soil with poor quality may not possess all of the attributes required for good agricultural production, or it may be prone to environmental degradation (Reynolds et al., 2007). Soil with good physical qualities has the ability to store and transmit water, air and nutrients in maximum productivity conditions and minimum environmental conditions (Topp et al., 1997). The growth and development of plants, hydric regime and soil solution are related to its physical properties (Hamza et al., 2005). The presence or absence of water stable aggregate on soil surface tends to an immediate effect on crust formation and on increasing hydric erosion of soils (Shouse et al., 1990). Soils shows at the surface an amounted percent of water stable aggregate, have a good resistance to hydric and aeolian erosion, comparative with the soil where the percent of unstable aggregate is sizable (Lehrsch et al., 2005). Soil structure undergoes change that leads to its degradation processes through structure, vulnerability to crust formation under the influence of direct and indirect rain, soil tillage and other factors (Canarache 1990; Yonts et al., 2001; Jitareanu et al., 2007).

Synthetic polymers added to different soils to improve soils physical, chemical and biological properties, have been studied by many researchers (Kulman A., 1962; Mandel M., 1988; Chiţanu G., 2005; Jităreanu et al., 2006; Voicu P., 2008), and the use of these polymers is known in the last 60 years by several works already accessible (Azzam R., 1980; DeBoodt M., 1990). Synthetic polymers added to soil as soil conditioners improve soil physical properties, are important for plant growth and increases soils resistance against disruptive forces and erosion (Öztaş T., 2002).

MATERIAL AND METHOD

The field experiments were conducted in 2006-2009 on a cambic chernozem soil, 6.8 pH, 2.7% humus content and a medium level of fertilization. The texture of the surface soil (0-30 cm) is clay-loamy with 40.3-41.8% clay content. The trial is a randomized block design with three replication, and two factors (AXB type). Plots covered an area of 18 m^2. The experimental variants were:

Factor A: tillage systems: a_1– ploughed at 30 cm; a_2– paraplow + vertical rotary harrow; a_3- paraplow + horizontal rotary harrow; a_4- chisel; a_5– disk harrow and Factor B: macromolecular compound: b_1-control variant b_2 - soil treated with 0.1% *Ponilit GT1* a.i. ha^{-1}; b_3 - soil treated with 0.3% *Ponilit GT1* a.i. ha^{-1}.

We studied the evolution of soil bulk density, total porosity, penetration resistance, and water stability of aggregates under the influence of

[1]University of Agricultural Sciences and Veterinary Medicine „Ion Ionescu de la Brad" Iasi, Romania

carboxylic polyelectrolyte *Ponilit GT1* (27.7% a. i). Soil samples were collected from different depths after sowing, during the growing period and at harvest time.

For determining water stability of aggregates from disturbed soil samples we used Kemper and Rosenau method (1986), a standard method according to Nimmo J.R. and Perkins K.S. (2002). We used a wet sieving apparatus (*Eijkelkamp Equipment)* that determines the percent of aggregates with water stability and those resistant to the dispersive action of sodium hydroxide in aqueous solution. Soil bulk density was determined with 5/5 cm and 100 cm^3 volume steel rings. The values were obtained by comparing absolute dry soil weight from the ring to its known volume. The penetration resistance of the soil was determined using a digital penetrologger *(Eijkelkamp Equipment, Model 0615-01 Eijkelkamp, Giesbeek, The Netherlands*) which had a cone angle of 60^o and a base area of 1 cm^2. 25 parallel records were made in each plot an averaged for statistical analysis. The ANOVA procedure was used for statistical analysis of the results.

RESULTS AND DISCUSSION

The aim of this study was to evaluate the effect of tillage systems and macromolecular compound *Ponilit GT1* on some soil physical properties from Ezareni-The Experimental Farm of Agricultural University of Iasi.

In all treatments, soil bulk density decreased in 0-5 cm layer compared to the control, because the soil became loose after polymer application. The looser soil permits more rainfall infiltration, facilitates microorganism movement and allows exchanges of water, gases and heat in the soil (*Wu S. et al 2010*). The results are in Table 1. Analyzing soil bulk density in 0-5 cm depth, this indicator had the lowest values (1.02-1.12 g cm^{-3}) in variant treated with 0.3% *Ponilit GT1*. The values increased to 1.13 and 1.16 g cm^{-3} respectively for 0.1% *Ponilit GT1* and control variant. In 12-17 and 22-27 cm layer, we observed that the concentrations of polymeric substances *Ponilit GT1* have no influence on bulk density values. No significant differences on 0-5, 12-17 and 22-27 cm depth were detected between soil treated with 0.1 and 0.3% polymeric substance *Ponilit GT1* and control variant. Total porosity an important indicator of soil conditions is reflecting soil settlement state. The *Ponilit GT1* treatments affected the total porosity values only in 0-5 cm layer and only on soil samples taken at sowing time.

Table 1

The influence of tillage system and polymeric substances on soil bulk density (g cm^{-3}) at soybean crop mean values 2006-2009

Tillage system	Dose (%)	Sowing			Growing period			Harvest		
		0-5 cm	12-17 cm	22-27 cm	0-5 cm	12-17 cm	22-27 cm	0-5 cm	12-17 cm	22-27 cm
Plough 30 cm	Control	1.11	1.22	1.31	1.22	1.33	1.38	1.27	1.39	1.42
	0.1%	1.07	1.22	1.31	1.22	1.33	1.38	1.27	1.39	1.43
	0.3%	1.07	1.21	1.31	1.22	1.33	1.38	1.27	1.40	1.43
Paraplow+ vertical harrow	Control	1.09	1.29	1.45	1.20	1.38	1.49	1.25	1.43	1.49
	0.1%	1.07	1.29	1.46	1.19	1.37	1.49	1.25	1.42	1.49
	0.3%	1.05	1.29	1.45	1.19	1.37	1.49	1.25	1.42	1.49
Paraplow+ orizontal harrow	Control	1.06	1.30	1.45	1.20	1.39	1.49	1.26	1.43	1.50
	0.1%	1.04	1.30	1.45	1.20	1.40	1.48	1.26	1.43	1.49
	0.3%	1.02	1.29	1.45	1.20	1.40	1.48	1.27	1.43	1.50
Chisel	Control	1.08	1.24	1.42	1.19	1.32	1.49	1.25	1.40	1.51
	0.1%	1.06	1.24	1.42	1.19	1.32	1.49	1.25	1.40	1.52
	0.3%	1.05	1.25	1.42	1.19	1.33	1.49	1.25	1.40	1.51
Disk harrow	Control	1.16	1.40	1.47	1.25	1.45	1.51	1.31	1.48	1.54
	0.1%	1.13	1.40	1.47	1.26	1.45	1.51	1.32	1.48	1.54
	0.3%	1.12	1.40	1.47	1.25	1.45	1.51	1.32	1.48	1.55

The total porosity values from 0-5 cm layer registered after sowing mean values between 56.35-60.00% at control variant and higher values between 57.36-60.88% and 57.74-61.38% at variants treated with 0.1 and 0.3% polymeric substances respectively. The application of *Ponilit GT1* to chernozem soil caused increases in total porosity; this may be due to micro structural development, which caused a high pore volume in this soil. On 12-17 and 22-27 cm depth no significant differences were detected. The penetration resistance varied only in 0-5 cm with the concentration applied. Penetration resistance decreased with concentration and only from sowing to emergence period. The smallest values were registered at 0.3% *Ponilit GT1* variant.

Carboxylic polyelectrolyte *Ponilit GT1* improves aggregate stability in soil and prevents dispersion of organic and mineral particles. Adding polymers changed the water stable aggregate content of the soil (Table 2).

Table 2

The influence of tillage system and polymeric substances on water stable aggregates at soybean crop mean values 2006-2009

Tillage system	Variant	Water stable aggregate	Statistical Significations
Plough 30 cm	Control	58.00	100.0 Mt.
	0.1%	69.00	119.0 xxx
	0.3%	74.50	128.4 xxx
Paraplow+vertical harrow	Control	55.00	100.0 Mt.
	0.1%	65.50	119.1 xxx
	0.3%	70.50	128.2 xxx
Paraplow+orizontal harrow	Control	54.50	100.0 Mt.
	0.1%	65.00	119.0 xxx
	0.3%	71.00	130.3 xxx
Chisel	Control	54.90	100.0 Mt.
	0.1%	65.20	118.8 xxx
	0.3%	71.85	130.9 xxx
Disk harrow	Control	53.80	100.0 Mt.
	0.1%	63.20	117.5 xxx
	0.3%	69.10	128.4 xxx

The higher improvements compared to the control occurred in the 0.3% *Ponilit GT1* treatment. The values of water stable aggregate registered at 0.1% polymer a.i ha^{-1} are higher with 17.5-19.3% compared with control variant and lower with 9.0-10.0% from 0.3 % polymer a.i ha^{-1} variant. From the point of view of concentration, the higher mean values of water stable aggregates were registered at the doses of 0.3% polymer a.i ha^{-1}, with minimum values registered by disk harrow (69.1%), and maximum values for ploughed at 30 cm variant (74.65%) chisel (71.25%) and paraplow variant (70.35 – 70.70%). This may be due to soil particles that were aggregate and most of the aggregates were water stable. The statistical analysis of mean values of water stable aggregate, have shown that the indicator registered higher values between 19% and 29% for 0.1% and 0.3% concentration respectively compared to control variant (55.2%), the difference being significant. The results registered, confirm the beneficial effect of *Ponilit GT1* on increasing hydric stability and improving soil structure quality.

CONCLUSIONS

The results of this study have shown beneficial effects of polymer *Ponilit GT1* applied on soil surface through the modification of its physical properties. It contributed to reduction of soil bulk density and penetrability and increases the content of water stable aggregate and soil porosity. Consequently the improved structure increased the seedling emergence and soybean yields. 0.3% *Ponilit GT1* variant had superior performance with respect to improvment of soil aggregate properties and performance of soybean crop compared with control variant. The values of soil bulk density in 0-5 cm depth decreased with increasing dose of *Ponilit GT1* application, which caused a high pore volume in this soil as suported by total porosity values. Increase the rate of application the higher the water stable aggregate and strength of individual aggregates against crushing forces.

REFERENCES

Azzam R. A. I., 1980 - *Agricultural polymers. Polyacrylamide preparation, application and prospects in soil conditioning, commun*. Soil sci. Plant analyses, 1-8, p. 67-83.

Canarache A., 1990 - *Fizica solurilor agricole*, Editura Ceres, Bucureşti.

Chiţanu G.C., 2002-2005 - Coordonator. *Noi materiale multifuncţionale pe baza de copolimeri maleici pentru protecţia mediului şi bioaplicaţii*, proiect Matnatech c.111, WWW.ICMPP.RO/~CHITA/.

DeBoodt M.F., 1990 - *Application of polymeric substances as physical soil conditioners. In soil colloids and their association in aggregates* (M.F.De Boodt). Plenum press, New-York.

Hamza M.A. Anderson W.K., 2005 - *Soil compaction in cropping systems: A review of the nature, causes and possible solutions.* Soil and Till. Res., vol. 82, issue, p. 121-145.

Jităreanu G., Chiţanu G.C., Filipov F., Harabagiu V., 2006 - *Improvement of some soi land horticultural substrata properties by using of maleic anhydride copolymers*. Inter, Soil Till. Res. Organ. 17 th Triennial Conf. Kiel, Germany, p. 804-809. ISBN: 3-9811134-0-3.

Jităreanu G., Ailincăi C., Ailincăi Despina, Zbanţ Mioara, Răus L., Bălan Adriana, Cara M.S., 2007 - *Evoluţia unor indici fizici şi agrochimici ai solului şi a producţiei sub influenţa fertilizării îndelungate*. Workshop, Iaşi. Ed. "I.I.Brad". ISBN 978-973-7921-94-9.

Kulman A., 1962 - *Uber den Einfluss einiger dungungesvarianten des Feldversuchesv Ewinger Roggenwan (Halle-S) and die Bodenstruktur*. Albrecht, Thaer. Arch., 6.

Lehrsch G.A., Bjorneberg D.L., Sojka R.E., 2005 - *Erosion: Irrigation-induced.* In Encycl. of Soils in the Environ. Ed. D Hillel. Vol. 1, pp. 445-463. Elsevier Ltd., Oxford.

Mandel M., **1988** - *Polyelectrolytes in encycl. Polym.* Sci. Eng., 2nd edn., john wiley and sons, vol. 11, p. 739-829.

Nimmo J.R., Perkins, K.S., 2002 – *Aggregate stability and size distribution, in Methods of soil Analysis Part 4- Physical methods*, Soil Science Society of America, Madison, WI, p. 317-328, ISBN 0891188479.

Öztaş T., Özbek A.K., Aksakal E.L., 2002 - *Structural developments in soil treated with Polyvinylalcohol*. Int. Conf. on Sust. Soil Sci. Soc. of Turkey Int. Symp. 143-148, Anakkale.

Reynolds W.D., Druly C.F., Yang X. M., Fox C.A., Tan C.S., Zhang T.Q., 2007 - *Land management effects on the near-surface physical quality of clay loam soil*. Soil Till. Research. 96: 316-330.

Rusu T., Paullette Laura, Cacovean H., Turcu V., 2007 - *Fizica, hidrofizica, chimia şi respiraţia solului.* Met. de cerc. Ed. Risoprint, Cluj Nap,p. 53-56. ISSN 978-973-751-512-4.

Shouse P.J., Gerik T.J., Russell WB., Cassel D.K., 1990 - *Spatial distribution of soil particle size and aggregate stability index in a clay soil*. Soil. Sci. 149 (6). 351-360.

Topp G.C., Reynolds W.D., Cook F.J., Kirby J.M., Carter M.R., 1997 - *Physical attributes of soil quality*. In:Gregorich, E.G., Carter,vol. 25. Elsevier, New York, pp. 21-58.

Tumsavas Zeynal, Tumsavas Fatma, 2011 - *The effect of polyvinyl alcohol (PVA) application on runoff, soil loss and drainage water under simulated rainfall conditions*. Journal of food agriculture and Environment Vol.9 (2):757-762.

Voicu P., 2008 - *Cercetări privind utilizarea polimerilor în Agricultură*. Ed. Bren. Bucureşti, ISBN 978-648-814-6.

Yonts C.D., Palm K.L., 2001 - *Irrigation management. In Sugarbeet Production Guide.* Ed. RG Wilson. Pp. 161-178. Univ. of Nebraska Coop. Ext. Bull. EC 01-156.

Wu S.F., Wu P.T., Feng H., 2010 - *Effect of the PPA on soil Physical properties and soil erosion under Artificial rainfall experiment in Loess Slope*. 2nd conference on environmental Science and information Application Technology, p. 48-51.

***__Soil Science Society of America__, **1997** - *Glossary of soil science terms.* Soil Science Society of America, Madison, WI.