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Influence of sodium polyacrylate on the water-holding capacity of three different soils and effects on growth of wheat

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Abstract. The effectiveness of sodium polyacrylate to increase soil water retention and to enhance growth of wheat under water deficit was evaluated. Water-holding capacity of the soils was considerably increased only when the soil was amended with the polymer at a rate $\geqslant 3\,\mathrm{g\,L^{-1}}$. The effect on plant-available water was greater at soil matric potentials up to –1000 hPa. The biomass and grain yield of plants without water deficit were increased by the polymer amendment, but decreased under severe water deficit stress. The polymer had no significant affect on plant N, grain N or grain Na content.

Keywords: Sodium polyacrylate, soil conditioner, hydrophilic polymer, water retention.

INTRODUCTION

Sodium polyacrylate is a cross-linked hydrophilic polymer that can swell up in water to hundreds of times its dry weight. The effectiveness of hydrophilic polymers in enhancing soil water retention or in increasing yield is dependent on formulation and soil type (Choudhary *et al.* 1995). Hydrophilic polymers have successfully increased yield of various crops (Baasiri *et al.* 1986; Dhliwayo 1993) and have been promoted for use as soil amendments for water conservation in water-deficient areas (Azzam 1983). The high cost of many polymers has usually restricted their use to high-value crops, but little is known about the use in agriculture of sodium polyacrylate, which is relatively cheap.

MATERIALS AND METHODS

The water retention capacity (WRC) of three soils (Table 1) amended with the polymer at 0, 1, 3, or $5\,\mathrm{g\,L^{-1}}$ of soil was tested in a pressure apparatus or, in a second approach, by placing the soils in pots with drain holes and then using tensiometers to monitor soil water tension changes due to gravity and air-drying. Water retention curves were estimated using RETC software (van Genuchten *et al.* 1991).

To test the effect of the polymer on plant growth, spring wheat (*Triticum aestivum* L. cv. Thassos) was sown in potting soil containing the polymer at 0, 0.1, 0.5, 1, or $3\,\mathrm{g\,L^{-1}}$ of soil. The plants were subjected to three water-deficit treatments (WDTs): no water-deficit stress, moderate or severe stress induced by restricting daily watering. Above-ground biomass was harvested from the pots, either before anthesis or at maturity. The plant material was analysed for total N and Na.

RESULTS AND DISCUSSION

Water retention capacity (WRC)

Considerable increases in WRC were observed only at polymer addition rates $\geqslant 3\,\mathrm{g\,L^{-1}}$, in particular with the sandy loam (Figure 1). The effect of the polymer on the WRC was larger up to –1000 hPa than at smaller soil matric potentials, indicating that the water retained by the polymer is readily available to the plant. Available soil water content (θ_{aw}) was greatest at the highest polymer rate (Table 2) except for the silty clay loam where the greatest θ_{aw} value was obtained at the $3\,\mathrm{g\,L^{-1}}$ rate. The effectiveness of the polymer decreased after rewetting (Figure 2).

Crop growth

Significant increases in biomass weight over the treatment without polymer were only found at maturity (Table 3). Across all WDTs, fresh matter biomass weight was significantly greater at an amendment rate of $\geqslant 0.5\,\mathrm{g\,L^{-1}}$ (dry matter weight only at $3\,\mathrm{g\,L^{-1}}$), within the moderate WDT only at a polymer rate of $3\,\mathrm{g\,L^{-1}}$, but within the severe WDT, no differences between the treatments, or even less biomass, were observed in the treatments containing the polymer.

Wheat grain yield per pot pooled across all WDTs was significantly ($P < 0.05$) increased only at the applied polymer rate of $3\,\mathrm{g\,L^{-1}}$. The polymer even seemed to exacerbate the effects of water deficit stress. Compared with the treatment without polymer, grain yield was increased without water

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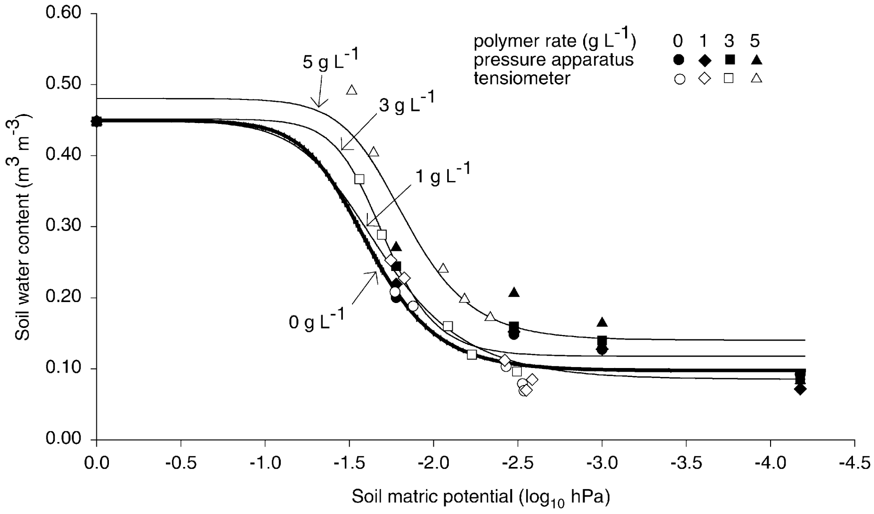

Figure 1. Example of a water retention curve. Sandy loam amended with different rates of sodium polyacrylate.

Table 1. Physical and chemical properties of of the three soils used in the experiment.

	Fine earth fraction (g kg^{-1})			Coarse fragments >2 mm (g kg^{-1} soil)	Electrical conductivity (mS cm^{-1})	Organic C (% dry matter)
	Clay <0.002 m	Silt 0.002–0.06 mm	Sand 0.06–2 mm			
Loam[a]	240	320	440	320	0.5	1.3
Silty clay loam[a]	370	410	220	550	0.4	1.7
Sandy loam[a]	120	160	720	40	0.2	1.1
Loam[b]	180	380	440	230	0.3	0.9

[a]For soil water retention trial; [b]for wheat growth trial.

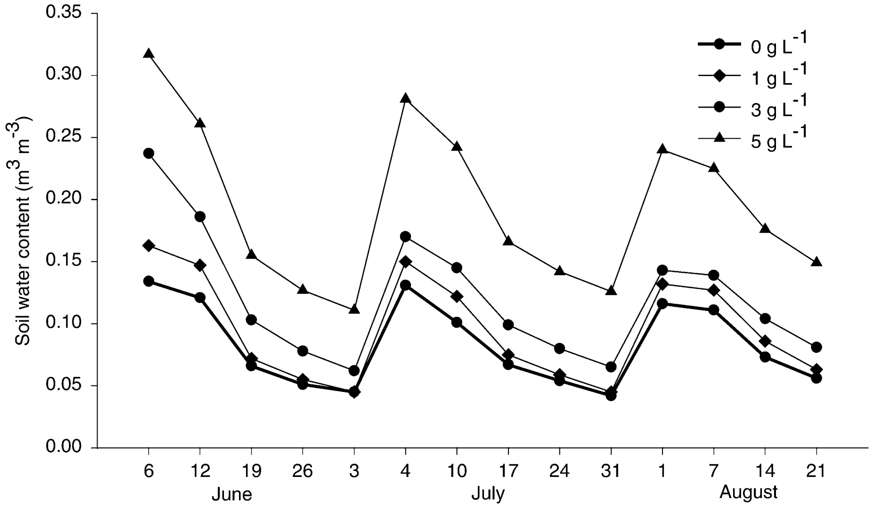

Figure 2..Example of soil water depletion induced by gravity and air-drying a sandy loam containing different rates of sodium polyacrylate as a function of time and drying cycle.

deficit stress at polymer rates of 0.5 and 3 g L^{-1}, within the moderate WDT at a rate of 1 g L^{-1}, but within the severe WDT the highest yields were found at the 0 and 0.1 g L^{-1} rates.

Table 2. Measured and RETC-estimated available soil volumetric water contents ($\theta_{aw,}$ $m^3 m^{-3}$) at four sodium polyacrylate (polymer) amendment rates.[a]

Polymer rate ($g L^{-1}$ soil)	Loam		Silty clay loam		Sandy loam	
	estimated	measured	estimated	measured	estimated	measured
0	0.13	0.15	0.13	0.16	0.11	0.11
1	0.12	0.14	0.14	0.17	0.15	0.15
3	0.13	0.15	0.15	0.20	0.13	0.16
5	0.16	0.17	0.13	0.18	0.19	0.19

[a] $\theta_{aw} = \theta_{15000\,hPa} - \theta_{300\,hPa}$ for silty clay loam and loam, and $\theta_{aw} = \theta_{15000\,hPa} - \theta_{60\,hPa}$ for sandy loam.

Table 3. Fresh and dry matter weight of biomass per pot at maturity, grain dry matter weight per pot, and N and Na content in dry matter of grain as affected by water stress and sodium polyacrylate (polymer) treatment.

	Polymer rate ($g L^{-1}$)													
	0	0.1	0.5	1	3	Mean	LSD	0	0.1	0.5	1	3	Mean	LSD
	Dry weight biomass ($g\,pot^{-1}$)							*Fresh weight biomass ($g\,pot^{-1}$)*						
No stress	42.2	41.7	45.2	44.7	47.7	44.3	2.5	44.0	49.2	52.7	51.8	54.8	50.5	5.8
Moderate stress	32.4	32.2	32.5	34.1	35.2	33.3	1.8	36.4	36.3	35.8	37.5	38.7	36.9	2.0
Severe stress	23.8	24.0	22.4	22.6	21.8	22.9	ns	26.1	23.5	24.5	24.7	23.7	24.5	2.1
Mean	32.8	32.7	33.4	33.8	34.9	33.5	1.1	35.5	36.4	37.7	38.0	39.0	37.3	2.0
LSD	2.0	2.9	1.9	1.7	1.9	0.9			7.1	2.8	2.0	2.9	1.9	1.6
	Dry weight grain ($g\,pot^{-1}$)													
No stress	21.3	21.1	22.9	22.0	25.1	22.5	1.4							
Moderate stress	17.4	16.8	17.0	18.3	19.4	17.8	1.4							
Severe stress	11.4	11.6	10.7	11.1	10.7	11.1	0.7							
Mean	16.7	16.5	16.9	17.1	18.4	17.1	0.7							
LSD	0.8	1.5	1.6	1.3	1.0	0.5								
	N content in grain ($g\,kg^{-1}$)							*Na content in grain ($mg\,100g^{-1}$)*						
No stress	24.1	24.1	22.5	22.2	22.3	23.0	0.8	9.4	10.0	11.9	12.6	13.0	11.4	ns
Moderate stress	27.0	27.3	27.8	27.1	27.3	27.3	ns	12.7	14.1	13.6	15.7	18.1	14.8	ns
Severe stress	32.8	32.2	34.0	33.6	34.2	33.3	1.1	11.6	17.5	17.2	17.3	19.6	16.6	4.0
Mean	28.0	27.8	28.1	27.6	27.9	27.9	ns	11.2	13.8	14.2	15.2	16.9	14.3	2.3
LSD	0.8	1.1	0.8	0.8	1.2	0.4		ns	5.0	2.8	ns	ns	1.8	

ns = not significant at P <0.05; LSD = least significant difference at P <0.05.

In most cases, grain N concentration was increased by higher polymer rates in the severe WDT, but decreased in the no WDT. The Na concentration in plant and, to a lesser extent in grain, generally increased with increasing polymer rate.

It can be concluded that sodium polyacrylate changes the hydraulic properties of soils only at high rates of application (around 3 t ha^{-1} to the first 30 cm soil depth), but it does not alleviate water deficit stress in wheat plants.

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