INFLUENCE OF HYDROGEL ON WATER CONSERVATION AND N UPTAKE BY BARLEY IRRIGATED WITH SALINE WATER: A POT STUDY

INFLUENCE DE L'HYDROGEL SUR LA CONSERVATION DE L'EAU ET LA CONSOMMATION DE L'AZOTE DANS L'IRRIGATION DE L'ORGE À L'AIDE D'EAU SALEE (ESSAI SUR LES POTS)

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ABSTRACT

In Serbia barley is sown in more than 90000 ha, and there is great potential for development of barley production. Due to the global climatic change, there is a shortage of clean irrigation water in Serbia so in Vojvodina, which is the most important agricultural region in Serbia, saline water present in that area are often used for irrigation.

The aim of this paper is to determine in a pot experiment the influence of applied polymers (hydrogels) on water consumption by the plants, as well as the influence of hydrogel on the soil and the biomass yield under saline water irrigation at various levels of nitrogen nourishment. The added hydrogel (potassium acrylate) in the dosage of 0.5% significantly influenced the change of water-physical properties of the sand, above all the quantity of available water. Hydrogel has considerable influence on reduction in water consumption during the testing period, as well as on better rooting and development of the barley root system. Level of nitrogen supply has not significantly influenced water consumption in different varieties but it has shown an influence on the production of biomass above the ground, while the influence of the irrigation water quality was statistically significant both with the quantity of irrigation water and with the production of above-ground biomass and the root.

Key words: *Hydrogel, Water conservation, N uptake, Saline water, Pot experiment.*

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RESUME ET CONCLUSIONS

En Serbie, l'orge est plantée sur plus de 90000 ha. De grands potentiels liés au développement de la production d'orge existent. A cause des besoins climatiques globaux, l'eau propre d'irrigation est de moins en moins présente en Serbie. De ce fait, pour l'irrigation, on utilise souvent, surtout en Vojvodine, région agricole serbe la plus importante, des eaux salées, très répandues dans cette région. D'autre part, les changements climatiques influent sur une augmentation du besoin d'eau dans la production agricole; le développement de différentes méthodes de conservation et de diminution de la consommation d'eau est, par conséquent, d'intérêt majeur.

L'objectif de cette étude est de déterminer l'influence des polymères appliqués (de l'hydrogel) sur la consommation d'eau par la plante ainsi que l'influence de ces matières sur le sol et l'apport de la biomasse dans des conditions d'irrigation à l'aide d'eau de mauvaise qualité à différents niveaux d'alimentation avec de l'azote. L'expériment a été organizé comme un schéma 2x2x3 factoriel arrangé en forme de blocs complets randomisés, repétés trois fois (sable pur avec hydrogel, deux qualités de l'eau pour irrigation et trois niveaux de N). L'orge a été plantée dans chaque pot et les jeunes plants étaient réduit à 10 plantes par pot. Le période total d'agrandissement a été 72 jours. L'expériment a été produit dans les pots plastiques avec le diamètre moyen de 23 cm et l'hauteur de 21 cm avec 2 kg de sable sec aéré. Lesniveaux de N ont été 60, 90, 150 kg N ha^{-1}, respectivement. P et K ont été préservés au niveau constant de 75 kg P ha^{-1}, 75 kg K ha^{-1}. L'hydrogel est ajouté dans une quantité de 5g/kg de sable. Pour l'irrigation, l'eau utilisée est l'eau de EC avec 5,74dSm-1 et 3,10 dSm-1 de la source naturelle de Torda en Vojvodine. Les pots par jour et l'ajout d'eau est effectué tous les 10 à 12 jours jusqu'à obtenir un bon approvisionnement d'eau. L'eau est ajoutée dans tous les pots en même temps. La diminution d'eau dans les pots a été suivie jusqu'au moment où l'humidité dans certains pots a été diminuée.

Au cours de l'expérience, des différences liées à la conservation de l'eau ont été déterminées. L'hydrogel appliqué a considérablement influé sur la consommation de l'eau au cours de la période de recherche.Les quantités d'eau utilisée sur un sable propre sont supérieures de 14,01 à 32,2% dans une variante avec une eau de mauvaise qualité et de 38,3 à 49,4% dans une variante d'eau irriguée de meilleure qualité. Quand il s'agit d'une consommation d'eau dans des variantes avec diverses qualités d'eau d'irrigation, dans les variantes avec l'hydrogel appliqué, il n'y a pas de différences sensibles quant à la consommation d'eau. Alors que dans les variantes avec un sable propre, la consommation est plus grande dans les conditions d'irrigation avec eau de meilleure qualité et ce, de 9,9 à 17,6%. Le niveau d'approvisionnement en azote n'a pas influé considérablement sur la consommation d'eau dans les différentes variantes. La production de biomasse est, dans les variantes d'essai avec l'hydrogel, supérieure de 1,1 à 24,5% par rapport à la variante avec une eau de moins bonne qualité alors que les différences dans les variantes avec une eau de meilleure qualité sont beaucoup moins exprimées. Dans toutes les variantes d'essai, les quantités d'azote ajoutées dans les variantes I et II n'ont pas influé dans une grande mesure sur les différences dans la biomasse alors que dans les variantes III avec un ajout de N, la quantité diminuée a eu un impact et une diminution de la biomasse dans toutes les variantes. Cependant, quand ilil s'agit de la masse de la racine, les différences sont énormes. Dans les variantes avec diverses qualités d'eau pour l'irrigation, la masse de la racine est est de 34,21 à 166,88% supérieure par rapport aux variantes avec une meilleure qualité d'eau alors que l'hydrogel *ajouté a influé pour que la masse de la racine soit supérieur de 2,33 à 4,73% par rapport au sable propre. L'ajout d'eau pour l'irrigation a suscité une légère augmentation des valeurs pH du sol sans montrer des différences statistiques sensibles dans les variantes d'essai.*

Mots clés : *Hydrogel, conservation d'eau, consommation de l'azote, eau salée, expérimentation menée dans un Pot.*

(Traduction française telle que fournie par les auteurs)

1. INTRODUCTION

In Serbia barley (Hordeum vulgare) is sown on more than 90000 ha. There is great potential for development of barley production. Due to the global climate change, there is a shortage of clean irrigation water in Serbia. In Vojvodina, which is the most important agricultural region in Serbia, saline water present in that area is often used for irrigation (Nesic, 2003). Irrigation with saline water carries the risk of soil salination. However, there are periods when only poor quality water is at the disposal so in some situations it is necessary to use this water for irrigation. In these situations, if there are limited quantities of better quality water available there is also the possibility of mixing i.e. diluting the saline water so as to overcome periods of water shortage. On the other side, climate changes increase of need for water in agricultural production. So it is important to develop different methods for conservation and reduction of irrigation consumption. When it comes to sandy soils, their productivity is mainly limited by bad water and air properties, low field capacity and low available water, as well as by high losses through percolation.

Gel-forming polymers were first introduced for agricultural use in the early 1980's. Application of hydrogels has an influence on improvement of aggregate content and increase in water retention in the soil at all suctions (from 0 - 15 atm), and the available water is significantly increased (El-Hady and Abo-Sedera, 2006, Owczarzak, 2006). The biggest increase of retention capacity is in the range of pF 0–2.2 which may influence retention of gravitational water and creation of unfavourable conditions for the plants (Leciejewski, 2009). Hydrogel influences the increase of efficiency of water usage and decrease of irrigation frequency (Johnson, 1984, Sivapalan, 2006). El-Hady (2009) states that the applied Acrylamide Hydrogels also have influence on an increasing OM, organic carbon and total nitrogen in the soil and increasing N, P and K in the treated soil. Produced yields by the unit of either irrigation water or added fertilizers refer to the beneficial effects of the examined hydrogel for reducing water consumption and increasing both water and fertilizers use efficiency by plants (El-Hady and Wanas, 2006). The applied hydrogels influence the production of CO_2, disintegration of cellulose and enzymatic activity and may be used as eco-friendly water-saving materials (Sarapatka, 2004). Water storage properties of different soil conditioners are significantly affected by the nature and concentrations of dissolved salts in irrigation waters (Johnson, 1984).

The aim of this paper is to determine in a pot experiment the influence of applied polymers (hydrogels) on water consumption by the plants, as well as the influence of these matters on the soil and the biomass yield in the conditions of irrigation with poor quality water at various levels of nitrogen nourishment.

2. MATERIALS AND METHODS

The experiment was a 2x2x3 factorial experiment arranged in a randomized complete block design, replicated 3 times. Barley was planted in each pot and seedlings were thinned to 10 plants/pots soon after germination. The total growing period of the crop was 72 days. The pots were in a greenhouse, and their weight and condition of soil moistness were measured daily. Sand was used for the experiment (Table 1).

Table 1. Particle-size distribution (La distribution granulométrique)

Granulometric composition (%)					
Total Sand 50-2000µm				Silt 50–2µmm	Clay < 2µm
2000-1.000µm	1.000-500µm	500-250µm	250-50µm		
29	28	30	17	4	2

The experiment was carried out in closed plastic pots with a mean diameter of 23 cm and a height of 21 cm with 2 kg of air dry sand. The levels of N were 60, 90 and 150 kg N ha^{-1}, respectively, both P and K were kept constant at a level of 75 kg ha^{-1}. Hydrogel (potassium polyacrylate) was added @ 5g/kg of sand. Water with EC of 5.74 dS m^{-1} and 3.10 dS m^{-1} was used for irrigation. For this, the undiluted local natural spring water (Torda) was used for the higher salinity treatment and diluted spring water was used for the lower salinity treatment. Chemical content of irrigation water is shown in Table 2.

Table 2. Analysis of irrigation water used (Analyse de l'eau d'irrigation utilisée)

Source	pH	EC	Soluble cations (meq/l)				Soluble anions (meq/l)		
		dSm^{-1}	Na^+	K^+	Ca^{++}	Mg^{++}	HCO_3^-	Cl^-	SO_4^{--}
I water	7.4	5.74	45,2	0.04	2.7	13.9	16.7	7.3	24.8
II water	7.5	3.10	22.7	0.06	1.3	7.1	9.1	7.3	12.9

Soil - water characteristic curves were determined by the pressure plate apparatus (Richards, 1948). Pots were measured daily and water was added every 10-12 days to all the in pots with hydrogel. Water filled up to field capacity. Decrease of water in pots was monitored up to the moment when some pots attained wilting percentage. Pots with sand without hydrogel were watered at shorter time intervals (2 to 4 days). Their moistness was maintained between 10KPa (field capacity) and wilting percentage (1.5MPa). Water was added simultaneously to the all pots with sand without hydrogel. That way the moistness of the soil both in pots with hydrogel and without hydrogel was always within the limits of available water.

3. RESULTS AND DISCUSSION

Sivapalan, (2006) states that by adding the polyacrylamide, water holding capacity of the soil exposed to 0.01 MPa pressure was increased by 23 and 95% by adding 0.03 and 0.07%

of polyacrylamide to the soil, respectively, but that at greater pressures (1.5 MPa) these differences are not pronounced. However, in this research it was determined that by adding the potassium polyacrylate to the concentration of 0.5% and at pressure of 1.5MPa there is a great difference. There is a considerably greater quantity of water at the hydrogel retained after exposure to the pressure of 1.5 MPa. (5.10 and 21.04 resp, table 3). The quantity of available water was increased at the hydrogel variety by 3.38 times. (on dry weight basis).

Table 3. Effect of hydrogel on some properties of sand (Effet de l'hydrogel sur certaines propriétés du sable)

	Water holding capacity	Field capacity (FC)%	Wilting percentage (WP)%	Available moisture %	Bulk density g/cm^3	Total porosity %
Sand	20.82	5.10	1.71	3.39	1.75	33.96
Sand + Hyidrogel	37.76	21.04	9.56	11.48	1.28	51.70

During the experiment differences in water consumption were determined (Table 4). The applied hydrogel had a significant influence on water consumption during the testing period. Quantities of spent water on clean sand are greater by 14,01-32,2% in the variety with poor quality water, i.e. 38,3-49,4% in the variety irrigated with better quality water. Apart from smaller water quantity, a positive effect was also demonstrated through prolongation of watering intervals. When it comes to water consumption in varieties with diverse irrigation water quality, with varieties with the applied hydrogel there are no significant differences in water consumption while with varieties with clean sand, water consumption was greater in conditions of irrigation with better quality water by 9,9-17,6%. Level of supply with nitrogen did not greatly influence water consumption in different varieties. Production of the above ground biomass is greater in varieties of the experiment with the hydrogel 1,1-24,5% in the variety with poor quality water while differences in the variety with better quality water are much less pronounced. Previous research of water irrigation from the spring (Dragicevic, 2000) demonstrated that salted mineral water did not influence the change in salad yield but certain changes in chemical content (content of phosphorus, potassium, sodium, vitamin C, and B-carotene is unchanged, but there was a decrease in the content of nitrogen).

In all varieties of the experiment the added quantities of nitrogen in varieties I and II have not influenced significantly the changes in the biomass, while in variety III of the added N, the decreased quantity reflected on the decrease in biomass in all varieties. However when it comes to the root mass, the differences are great. Even though the varieties with and without hydrogel were provided with the same quantity of nourishing matter, the sand was unstructured, so in the pots with hydrogel development of the root system is much better. The added hydrogel caused the root mass to be greater by 2,33-4,73 than on the clean sand. In the varieties with different irrigation water quality the root mass is by 34,21-166,88% greater than in varieties with better quality water.

Table 4. Water consumption, biomass of the section above ground and biomass of roots in the pots (La consommation d'eau, la biomasse de la section-dessus du sol et la masse de la racine)

Amount of K polyacrilate in soil g/kg	Fertilizer doses	Irrigation water	Amount of water used in 72 days l/pot	Biomass of the section above ground g/pot	Biomass of the root g/pot
5	N1	I	1.75	2,59	4.92
5	N2	I	1.88	2,43	4.53
5	N3	I	1.61	1,90	3.81
5	N1	II	1.78	2,56	6.60
5	N2	II	1.70	2,25	6.80
5	N3	II	1.63	2,08	7,27
0	N1	I	2.13	2,08	1.29
0	N2	I	2.15	2,05	0.96
0	N3	I	2.13	1,88	1.07
0	N1	II	2.50	2,68	2.21
0	N2	II	2.35	2,34	2.93
0	N3	II	2.43	2,14	2.85

Statistical analysis of the experimental data and assessments of their significance was done by the method of variant analyses for three-factorial experiment set up according to a random plan. Hydrogel has a great influence on the dependant occurrence (water consumption) as well as water quality which has somewhat smaller significance than the hydrogel. The factor of fertilizer dose does not have a statistically significant influence on water consumption ($p>0.05$). Interaction of the tested factors hydrogel x water quality which demonstrated the statistical significance has great influence on water consumption. When it comes to the yield of the biomass of the section above the ground, it is slightly bigger with the use of hydrogel (2.30 g), compared to the situation when hydrogel is not used (2.21 g). Fertilizer dose was most beneficial to the yield of the biomass of the section above the ground (2,48g), while the dose III was the least favourable to the yield (2.00 g). Yield of the biomass of the section above the ground is almost equally determined both by the fertilizer dose and the water quality while the yield of the root biomass is determined by the hydrogel and water quality.

4. CONCLUSIONS

The applied potassium polyacrylate in concentration of 0.5% influenced the change in some water and physical sand properties. The quantity of available water was increased and water retention in the soil at all suctions (from 0 - 15 atmo). The applied hydrogel influenced the reduction in the quantity of added water and watering intervals. The applied hydrogel and the irrigation water quality have influence on water consumption, while the production of the above ground biomass is mostly influenced by the applied fertilizer dose and somewhat less by the irrigation water quality. Hydrogel influences equal development of the root system and greater biomass of the root. By using the hydrogel it is possible to achieve great savings of irrigation water.

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