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THE EFFECT OF AGROHYDROGEL AND IRRIGATION ON KOHLRABI CV 'OASIS F_1' YIELDS

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Abstract. Under the climatic conditions of Poland cultivation without irrigation does not assure high yields of good quality. Of the many types of irrigation, drip irrigation is most economical in terms of water use efficiency. An application of hydrogels – compounds which are capable of storing large volumes of water – is an alternative to very expensive irrigation systems. In the experiment was investigated the effect of irrigation (no irrigation, irrigation by means of a dripping tape) and method of AgroHydroGel application (control, AgroHydroGel applied under seedlings, AgroHydroGel applied under plants in the field, half of the AgroHydroGel rate applied under seedlings, the other half under plants in the field) on the yield level and quality of kohlrabi grown in the field. Irrigation significantly increased yields as well as the average weight and diameter of bulb, however, it had no influence on the nutrient contents. Application of AgroHydroGel under plants in the field influenced the most favourable on the yielding. An application the whole AgroHydroGel rate under seedlings, the whole rate under plants in the field as well as at a split rate in the irrigated combination contributed to significant increase marketable bulb yields as compared to the control without hydrogel. The most ascorbic acid and total sugars contents kohlrabi bulb from the treatments in which AgroHydroGel had been applied under plants in the field or at a split rate.

Key words: kohlrabi (*Brassica oleracea* L. var. *gongylodes* L.), yield, superabsorbent, dripping tape, nutritive value

INTRODUCTION

Under the weather conditions of Poland there are frequent water shortages due to insufficient precipitation over the growing period. It results in fluctuating yields and unstable yield quality. Substantial variation in weather conditions makes it necessary to replenish soil water deficit increases by means of irrigation. Of the many types of irriga-

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tion, drip irrigation is most economical in terms of water usage. The system moistens small soil areas, which reduces water losses due to evaporation. Frequent applications of small water amounts reduce losses of water caused by water flowing out of the root zone [Kaniszewski 2005]. Beneficial effects of drip irrigation on vegetable yields and yield quality have been confirmed in the studies by Spiżewski and Knaflewski [2000], Podsiadło et al. [2003], Rolbiecki and Rolbiecki [2005], Rożek [2005], Rolbiecki et al. [2009].

However, because of high costs of irrigation, attempts have been made to find solutions aiming at reduction of water usage. One of the ways to achieve this in horticulture is to amend soil with polymer superabsorbents called hydrogels. Hydrogels are capable of absorbing considerable volumes of plant-available water. These properties of superabsorbents enable plants to maintain growth at reduced watering [Hetman at al. 1998]. According to Paluszek [2003], hydrogel-based production results in plants with more developed root systems as superabsorbents create optimal air and water conditions for root growth. High hydrogel usefulness in lettuce cultivation has been reported by Woodhouse and Johnson [1991], Chatzoudis and Valkanas [1995], Wierzbicka et al. [2002] and Majkowska-Gadomska [2006], in pepper by Jabłońska-Ceglarek et al. [1999], in cabbage by Biesiada et al. [1997], and in tomato, cabbage and lettuce by Kołota and Krężel [1995].

The objective of the present work was to determine the effect of AgroHydroGel added to the substrate and irrigation on the yield level and quality of kohlrabi cv 'Oasis F_1'.

MATERIALS AND METHODS

A field experiment was carried out from 2007–2009 at the University of Natural Sciences and Humanities experimental unit in Siedlce. The trial was set up as randomized blocks with three replications. The experiment was conducted on anthropogenic soil with hortisol properties which, as part of a horticultural farm, has long been used for horticultural purposes. It was a neutral-pH soil characterized by an approximately 40 cm deep humus layer and an average organic carbon content ranging between 2.3 and 2.5% (tab. 1). The available phosphorus content was below the optimum limit whereas nitrogen, potassium, magnesium and calcium contents were slightly above the limit for field-grown kohlrabi [Sady 2000]. Basic soil preplant fertilization included Azofoska at a rate of 10 kg per 100 m^2 cultivated area.

Effects of the following factors were examined:

a) irrigation

– no irrigation,

– irrigation by means of a dripping tape,

b) method of AgroHydroGel application

– control without AgroHydroGel,

– AgroHydroGel applied under seedlings (54 g under seedlings planted in 1 plot),

– AgroHydroGel applied under plants in the field (54 g per 1 plot),

– half of the AgroHydroGel rate applied under seedlings (27 g under seedlings planted in 1 plot), the other half under plants in the field (27 g per 1 plot).

Table 1. Characteristic of soil conditions before experiment placing (available food components contents)

Tabela 1. Charakterystyka warunków glebowych przed założeniem doświadczenia (zawartość łatwo przyswajalnych składników pokarmowych)

Years – Lata	pH	C-org %	$N\text{-}NO_3$	$N\text{-}NH_4$	P	K	Ca	Mg
			$mg \cdot dm^3$ air dry mass – powietrznie suchej masy					
2007	6.6	2.3	33.3	48.6	51.2	153.6	2270.7	71.7
2008	6.9	2.5	35.8	53.8	46.1	192.0	2306.6	66.6
2009	7.1	2.4	28.2	61.4	48.6	209.9	2342.4	64.0
Mean Średnio	6.9	2.4	32.4	54.6	48.6	185.2	2306.6	67.4
Optimum limit Wartości optymalne [Sady 2000]	6.0–7.0	-	75–90		50–60	130–160	1000–1500	55–65

The aim of the study was to evaluate the effect of the factors investigated on the yield level and quality of kohlrabi cv 'Oasis F_1' grown in the field under the climatic conditions of central-eastern Poland.

Kohlrabi seedlings were produced in a non-heated greenhouse. The seeds were sown at the rate of 0.3 g in late March to seedling containers with peat substrate amended with AgroHydroGel or peat substrate only. The seedlings destined for planting in the control were grown only on peat substrate. The seedlings intended for planting in the plots in which the whole AgroHydroGel rate applied under the seedlings were grown on peat substrate with an addition of 54 g hydrogel. The seedlings to be planted in the plots with hydrogel applied in the whole rate under plants in the field were grown on peat substrate. The seedlings for planting in the treatment, in which half the rate of AgroHydroGel was to be applied under seedlings and the other half under plants in the field were grown on peat substrate with 27 g hydrogel. In the plots where AgroHydroGel was to be soil-incorporated, rows were marked and then soil was collected from 20 × 20 cm strips (width × depth) and mixed with hydrogel.

Prior to transplanting the seedlings were hardened off and then moved permanently outdoors and planted in late April at a spacing of 15 × 30 cm. The whole plot area was 1.2 × 2.4 m.

The dripping tape TSX508-15-1000/20-500 was installed in the irrigation sub-block. Kohlrabi irrigation was applied as needed depending on weather conditions. Soil samples were collected once a day to determine soil moisture. The irrigation system was turned on when the soil moisture was below 10% and when it exceeded 15% the system was turned off.

The kohlrabi was harvested two times at 7–10 days intervals, at a minimum bulb diameter of 3 cm. The beginning of harvest was after 50–51 days from the planting of seedlings. During the harvest there was determined the total and marketable bulb yield ($kg \cdot m^{-2}$), the average weight of marketable bulb (g) and bulb diameter (cm). No marketable yield determined disease-affected, cracked and overgrew bulb. From each plot a bulb sample (10 bulb) was taken to perform chemical analyses in order to determine the following contents: dry matter (%) – using the oven-drying gravimetric method,

ascorbic acid (mg·100 g^{-1} FM) – using the Tilmans method, and total sugars (% FM) – using the Luff Schoorl method.

The results of the experiment were analysed statistically by means of the analysis of variance. The significance of differences was checked using Tukey test at the significance level of $\alpha = 0.05$.

Table 2. Mean air temperature in the vegetation period of kohlrabi
Tabela 2. Średnie temperatury powietrza w okresie wegetacji kalarepy

Years Lata	Temperature – Temperatura (˚C)															
	April – Kwiecień				May – Maj				June – Czerwiec				July – Lipiec			
	I*	II	III	mean średnio	I	II	III	mean średnio	I	II	III	mean średnio	I	II	III	mean średnio
2007	6.0	9.4	9.5	8.3	9.1	14.1	20.3	14.5	18.2	20.0	16.3	18.2	16.6	20.5	18.4	18.5
2008	7.3	8.5	10.5	8.8	11.5	13.2	12.9	12.5	17.6	15.9	17.6	17.0	17.4	17.9	18.9	18.1
2009	9.5	8.4	12.1	10.0	12.4	12.0	14.1	12.8	13.8	14.4	19.1	15.8	19.0	19.8	19.1	19.3
Mean Średnio 1951–1990				7.2				13.2				16.2				17.6

*decade – dekada I, II, III

Table 2 summarizes thermal conditions in the kohlrabi growing seasons. The years 2008 and 2009 were more favourable for the growth and development as the air temperatures and their distribution were more beneficial for kohlrabi. In 2007, late April and early May were cool whereas late May and first half of June were very hot. Such a temperature distribution in the growing season had an unfavourable effect on kohlrabi growth and yielding.

RESULTS AND DISCUSSION

Irrigation increased total bulb yield and marketable yield by 22% and average bulb weight by 25% as compared to the non-irrigated plots (tab. 3). These findings were confirmed in the research by Podsiadło et al. [2003] in which drop irrigation enhanced the marketable and total yield of tomato by 29 and 20%, respectively. In the study by Rożek [2005], marketable celeriac yield increased by 71%, on average, as influenced by irrigation. Rolbiecki et al. [2009] found that drip irrigation increased watermelon yield by an average of 156%, whereas in the study by Rolbiecki et al. [2006] the marketable yield of pumpkin fruits was increased by 50%.

The method of AgroHydroGel application significantly influenced the yields of kohlrabi and average bulb weight (tab. 3). Significantly higher total and marketable yield and average bulb weight were obtained in the treatments in which AgroHydroGel had been applied under plants in the field in comparison with the control without the superabsorbent. The differences in yields amounted to 0.85 and 0.86 kg·m^{-2}, respectively and in the average weight of bulb 42.2 g. AgroHydroGel applied under seedlings and as split rate (half rate under seedlings and half under plants in the field) did not

Table 3. Kohlrabi yields and size of bulb depending on irrigation and method of AgroHydroGel application (mean for years 2007–2009)

Tabela 3. Plonowanie kalarepy i wielkość zgrubień w zależności od nawadniania i sposobu stosowania AgroHydroGelu (średnia z lat 2007–2009)

	Irrigation Nawadnianie	Method of AgroHydroGel application Sposób stosowania AgroHydroGelu				Mean Średnio
		I*	II*	III*	IV*	
Total yield Plon ogółem kg·m^{-2}	no irrigation bez nawadniania	3.44	3.83	4.41	3.78	3.87
	irrigation nawadnianie	4.52	4.94	5.24	5.14	4.96
	mean – średnio	3.98	4.38	4.83	4.46	4.41
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irriagtion – nawadniania = 0.42; method of AgroHydroGel application – sposobu stosowania AgroHydroGelu = 0.68; irrigation – nawadnianie × method of AgroHydroGel application – sposób stosowania AgroHydroGelu = n.i. – n.s.						
Marketable yield Plon handlowy kg·m^{-2}	no irrigation bez nawadniania	2.81	3.46	3.97	3.38	3.40
	irrigation nawadnianie	4.04	4.18	4.60	4.66	4.37
	mean – średnio	3.42	3.82	4.28	4.02	3.89
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irriagtion – nawadniania = 0.29; metod of AgroHydroGel application – sposobu stosowania AgroHydroGelu = 0.77; irriagtion – nawadnianie × metod of AgroHydroGel application – sposób stosowania AgroHydroGelu = 0.10						
Average weight of marketable bulb Średnia masa zgrubienia handlowego g	no irrigation bez nawadniania	144.0	169.6	194.0	163.9	167.9
	irrigation nawadnianie	201.3	219.9	235.9	234.7	222.9
	mean – średnio	172.7	194.7	214.9	199.3	195.4
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irrigation – nawadniania = 19.1; metod of AgroHydroGel application – sposobu stosowania AgroHydroGelu = 35.0; irrigation – nawadnianie × metod of AgroHydroGel application – sposób stosowania AgroHydroGelu = n.i. – n.s.						
Bulb diameter Średnica zgrubienia cm	no irrigation bez nawadniania	6.47	6.84	7.34	6.97	6.91
	irrigation nawadnianie	7.24	7.55	7.18	7.48	7.36
	mean – średnio	6.86	7.20	7.26	7.23	7.14
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irriagtion – nawadniania = 0.33; metod of AgroHydroGel application – sposobu stosowania AgroHydroGelu = 0.32; irriagtion – nawadnianie × metod of AgroHydroGel application – sposób stosowania AgroHydroGelu = 0.59						

*I – control – kontrola, II – AgroHydroGel applied under seedlings – AgroHydroGel zastosowany pod rozsadę, III – AgroHydroGel applied under plants in the field – AgroHydroGel zastosowany pod roślinę w gruncie, IV – half of the AgroHydroGel rate applied under seedlings, the other half under plants in the field – połowa dawki AgroHydroGelu zastosowana pod rozsadę, połowa pod roślinę w gruncie

significantly increase the yields and average bulb weight compared with the control without the sorbent. In the study by Majkowska-Gadomska [2006] the average total and marketable yields of lettuce were by 1.87 kg·m^{-2} higher, as a result sorbent application, in comparison with the yield achieved from the control. These findings were confirmed in the research by Majkowska-Gadomska and Wierzbicka [2005] where potassium Akrygel contributed to an increased marketable lettuce yield of 2.05 kg·m^{-2}, on average.

In the study by Biesiada et al. [1997], an incorporation of superabsorbents to the soil improved the growth of plants and, as a result, enhanced the total and marketable yield of cabbage as well as yield of grade I heads. The authors did not find any differences in yields depending on the type of hydrogel applied (Ekogel, Akrygel) or its form (powder, gel solution). Jabłońska-Ceglarek et al. [1999] showed that the yield of pepper cultivated in the soil amended with superabsorbent did not differ significantly as compared to the control yield.

Table 4. The nutrient contents in kohlrabi bulbs depending on irrigation and method of AgroHydroGel application (mean for years 2007–2009)

Tabela 4. Zawartość składników odżywczych w zgrubieniach kalarepy w zależności od nawadniania i sposobu stosowania AgroHydroGelu (średnia z lat 2007–2009)

	Irrigation Nawadnianie	Method of AgroHydroGel application Sposób stosowania AgroHydroGelu				Mean Średnio
		I*	II*	III*	IV*	
Dry matter Sucha masa %	no irrigation bez nawadniania	9.18	9.76	9.32	9.03	9.32
	irrigation nawadnianie	8.89	9.02	8.71	9.35	8.99
	mean – średnio	9.04	9.39	9.02	9.19	9.16
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irriagtion – nawadniania = n.i. – n.s.; method of AgroHydroGel application – sposobu stosowania AgroHydroGelu = n.i. – n.s.; nawadnianie × method of AgroHydroGel application – sposób stosowania AgroHydroGelu = n.i. – n.s.						
Ascorbic acid mg·100 g^{-1} FM Kwas askorbinowy mg·100 g^{-1} św. m.	no irrigation bez nawadniania	61.02	68.30	65.37	70.55	66.31
	irrigation nawadnianie	62.48	62.52	67.22	61.96	63.54
	mean – średnio	61.75	65.41	66.29	66.25	64.93
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irrigation – nawadniania = n.i. – n.s.; method of AgroHydroGel application – sposobu stosowania AgroHydroGelu = 1.27; irrigation – nawadnianie × method of AgroHydroGel application – sposób stosowania AgroHydroGelu = 6.40						
Total sugar % FM Cukry ogółem % św. m.	no irrigation bez nawadniania	3.68	3.88	4.04	4.13	3.93
	irrigation nawadnianie	3.83	3.87	3.96	4.02	3.92
	mean – średnio	3.76	3.87	4.00	4.08	3.93
$LSD_{0.05}$ for – $NIR_{0,05}$ dla: irriagtion – nawadniania = n.i. – n.s.; method of AgroHydroGel application – sposobu stosowania AgroHydroGelu = 0.08; irrigation – nawadnianie × method of AgroHydroGel application – sposób stosowania AgroHydroGelu = n.i. – n.s.						

*I – control – kontrola, II – AgroHydroGel applied under seedlings – AgroHydroGel zastosowany pod rozsadę, III – AgroHydroGel applied under plants in the field – AgroHydroGel zastosowany pod roślinę w gruncie, IV – half of the AgroHydroGel rate applied under seedlings, the other half under plants in the field – połowa dawki AgroHydroGelu zastosowana pod rozsadę, połowa pod roślinę w gruncie

There was found an interaction between irrigation and the method of AgroHydroGel application in terms of the marketable yield as well as bulb diameter (tab. 3).

In the non-irrigated treatments, significantly the highest marketable bulb yields were harvested from the plots in which the whole AgroHydroGel rate had been applied under plants in the field. The yields were significantly lowest in the control with no hydrogel.

In the irrigated treatments significantly higher yields were obtained in the plots with hydrogel applied under plants in the field and in the plots where AgroHydroGel had been applied at split rates (half under seedlings and half under plants in the field) in comparison with the remaining treatments. The yield was significantly the lowest in the control.

The effect of AgroHydroGel on bulb diameter was observed only in the non-irrigated treatments. Significantly higher bulb diameters were measured in the plots where AgroHydroGel had been applied under plants in the field as compared to the control without hydrogel. Borowski and Michałek [1998] showed that hydrogel added to the soil favourably influenced lettuce yields when combined with periodic watering. The authors claim that this favourable effect of hydrogels is a result of enormous possibilities of accumulation in the soil of plant-available water. In the study by Kołota and Krężel [1995] the best production effects in tomato and head cabbage cultivation were obtained when an Akrygel-amended substrate was used and plants were watered regularly. In turn, the highest lettuce yields of the best quality were harvested from the non-irrigated treatment. According to Gudarowska and Szewczuk [2009], agrogel had a significant influence on the diameter and height of Pumiselect® rootstocks (which come from *Prunus pumila*) propagated through hardwood cuttings. There cuttings were higher and thicker than cuttings rooted in the control plot. Also, an application of agrogel and irrigation had a favourable influence on branching of cuttings in the first year in the nursery.

There was found no interaction between the factors investigated and study years.

The factors examined in the study did not change the dry matter content of kohlrabi but they significantly influenced the ascorbic acid and total sugars contents (tab. 4). In the non-irrigated treatments significantly higher ascorbic acid contents were found in the kohlrabi bulbs harvested from the plots where hydrogel had been applied under seedlings or at a split rate – half under seedlings, half under plants in the field. Significantly most total sugars were determined in the plots where AgroHydroGel had been applied at a split rate whereas the least amount in the control without hydrogel. Spiżewski and Knaflewski [2000] reported no significant influence of irrigation on the dry matter and vitamin C contents of cabbage heads. Also, Rolbiecki et al. [2006] found no significant influence of irrigation on the dry matter, sugars, vitamin C and carotenoids contents in the fresh matter of pumpkin fruit. Studies by Rolbiecki and Rzekanowski [1996] showed that irrigation decreased dry matter content of French bean and red beet yields, and vitamin C in tomato fruit, French bean, red beet and carrot. In the study by Majkowska-Gadomska [2006] an addition to the soil of a sorbent increased dry matter, vitamin C as well as organic acid contents in lettuce leaves. However, studies by Majkowska-Gadomska and Wierzbicka [2005] did not demonstrate significant changes in the dry matter, L-ascorbic acid and organic acid contents in lettuce as a result of an addition of superabsorbents to the soil. Jabłońska-Ceglarek et al. [1999] found that superabsorbents incorporated to the soil had an insignificant effect on the dry matter and vitamin C contents in pepper. Only potassium Ekosorb application was followed by a noticeable increase this components in pepper.

There was found no interaction between the factors examined and study years.

CONCLUSIONS

1. Irrigation significantly increased total and marketable bulb yields as well as the average weight and diameter of bulb, however, it had no influence on the nutrient contents in kohlrabi bulbs.

2. The highest increases in yields were recorded in the treatments where AgroHydroGel had been applied under plants in the field.

3. An application the whole AgroHydroGel rate under seedlings, the whole rate under plants in the field as well as at a split rate in the irrigated combination contributed to significant increase marketable bulb yields as compared to the control without hydrogel. Superabsorbent applied in the whole rate under plants in the field and at a split rate contributed to significantly higher increase the yield compared with the plots where AgrohydroGel was applied under seedlings.

4. An application of AgroHydroGel under plants in the field or at a split rate contributed to increased ascorbic acid and total sugars contents in kohlrabi bulbs.

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WPŁYW AGROHYDROGELU I NAWADNIANIA NA PLONOWANIE KALAREPY 'OASIS F_1'

Streszczenie. W warunkach klimatycznych Polski uprawa bez nawadniania nie gwarantuje wysokich i dobrej jakości plonów. Spośród wielu sposobów nawadniania, kroplowe charakteryzuje się najbardziej oszczędnym zużyciem wody. Alternatywą dla instalowania kosztownych systemów nawadniających jest stosowanie hydrożeli, związków charakteryzujących się dużymi zdolnościami magazynowania wody. W doświadczeniu badano wpływ nawadniania (bez nawadniania, nawadnianie taśmą kroplującą) i sposobu stosowania AgroHydroGelu (kontrola, AgroHydroGel zastosowany pod rozsadę, AgroHydroGel zastosowany pod roślinę w gruncie, połowa dawki AgroHydroGelu zastosowana pod rozsadę, połowa pod roślinę w gruncie) na wielkość i jakość plonu kalarepy uprawianej w gruncie. Nawadnianie istotnie zwiększyło plony, a także średnią masę i średnicę zgrubienia, ale nie powodowało zmian w zawartości składników odżywczych. Najkorzystniej na plonowanie wpłynęło zastosowanie całości hydrożelu pod roślinę w gruncie. Zastosowanie hydrożelu w całości pod rozsadę, w całości pod roślinę w gruncie oraz w dawce dzielonej w kombinacji z nawadnianiem przyczyniło się do istotnego wzrostu plonu handlowego zgrubień w porównaniu z kontrolą bez hydrożelu. Najwięcej kwasu askorbinowego i cukrów ogółem zawierały zgrubienia z obiektów, w których superabsorbent stosowano w całości do gruntu lub w dawce dzielonej.

Słowa kluczowe: kalarepa (*Brassica oleracea* L. var. *gongylodes* L.), plon, superabsorbent, taśma kroplująca, wartość odżywcza

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