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The influence of different doses of hydrogel on the quality of seeds and the yield of faba beans

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Abstract. The aim of the study was to evaluate the effect of hydrogel on the growth, development, yield and quality of faba bean seeds. A positive influence of the TerrahydrogelAqua hydrogel on the yield of faba beans compared to the control, where no hydrogel was used, was noted. While increasing the dose from 10 kg ha^{-1} to 30 kg ha^{-1} had a positive effect on seed yield at both locations in the wet year (2014) (in Błonie also in the dry year 2016), it had no significant effect on the yield in the other years. The use of hydrogel, as well as increasing its dose, had a relatively small effect on the content of the major nutrients in faba bean seeds. An increased concentration of ash was noted in those faba bean seeds, in whose production a dose of hydrogel amounting to 30 kg ha^{-1} was applied. The use of hydrogel in faba bean production had a positive influence on the weight of one thousand seeds, the number of seeds, the weight of seeds and number of pods per plant and the number of seeds per pod, while increasing the dose of hydrogel had no significant effect on the number of pods per plant.

Keywords: faba bean, hydrogel, doses

INTRODUCTION

The growing demand for plant protein as a raw material essential for the feed industry results in an increased interest in the production of faba beans for seeds. This species is characterized by high feed value and high yielding potential, but, at the same time, by its high sensitivity to drought. In particular, this applies to the germination stage because the amount of water collected during this time constitutes from 170% to 250% of the seed weight. In the case of faba beans, a good supply of water is also important in subsequent phases, in particular during the period of 20 days before flowering and 10 days after flowering, when the amount of water needed ranges from 120 to 140 mm (Dzieżyc, 1989). A shortage of water during this period causes the shedding of flower buds and flowers, and consequently the reduction in the number of pods and their irregular distribution on the fruiting part. In addition, there occurs a reduction in the number of pods per plant and a reduction in the weight of the seeds, which leads to a decrease in yield (Księżak, 2002). In the case of water shortage, a decrease in the nutritional value of seeds may also occur. The faba beans' response to the weather is stronger during the years characterized by the occurrence of heavy rains and longer periods of drought (Księżak, 2002). Effective ways of reducing the impact of adverse weather conditions on the growth and development of crops are being sought. Among the various solutions, there are high hopes for the use of superabsorbents (hydrogels), which are hydrophilic, macromolecular, cross-linked copolymers (De Boodt, 1990; Dechnik, Dębicki, 1986; Gabriels, 1990; Wallace, Wallace, 1986; Wallace, 1998). Superabsorbents are divided into two groups: ionic (cationic, anionic), e.g., cross-linked poly (acrylic acid) and non-ionic (e.g. polyacrylamide) (Lejcuś et al., 2008; Zhang et al., 2006). Hydrogel retains the water and nutrients dissolved in it and protects plant roots against excessive drying. Its specific feature is the ability to absorb and retain water and give it to plants during drought as needed. Water absorbed by the plants from hydrogels can be used easily because the root suction forces are usually greater than the forces binding water in superabsorbents (Lejcuś et al., 2008). In the process of repeated swelling and shrinkage caused by the water being drawn by plants, superabsorbents change the structure of the soil, causing it to loosen. The effect of hydrogels may also consist in the interruption of the continuity of soil micropores, which increases retention and reduces the evapotranspiration of soil (Helia et al., 1992; Fonteno, Bilderback, 1993) and prevents water and wind erosion (Ropek, Kulikowski, 2009). Furthermore, hydrogel retains the gravitational water in the soil, which, in natural conditions, would quickly permeate deep into the

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soil profile, thus no longer being available to plants (Leciejewski, 2009). The beneficial effect of adding hydrogel to the soil has been demonstrated with regard to the growth and yield of plants (Helia et al., 1992; Jabłońska-Ceglarek, Cholewiński, 1998) and the improved growth and development of the grass root system (Orzeszyna et al., 2006).

In the literature available, there are no reports on the effects of using hydrogel on the performance of faba beans. Therefore, research was undertaken to determine the effect of hydrogel on the growth, development, yield and quality of faba bean seeds of two types of cultivars: a high-tannin, determinate Granit and a low-tannin, indeterminate – Albus.

MATERIAL AND METHODS

The field experiments were carried out in the years 2014–2016 in the RZD Grabów (Agricultural Experimental Station in Grabów) (51°23'N, 21°38'E) and Błonie-Topola (52°07'N, 19°20'E) as four randomized blocks laid out in. The experiment evaluated the effect of TerrahydrogelAqua (cross-linked acrylic, potassium polymer) (Table 1) in the following doses: control – without hydrogel, 10, 20 and 30 kg ha^{-1}). The faba bean seeding rate (Grabów – Granit, Błonie – Albus) was 70 pcs/m^2. The plot size at sowing and at harvest was 100.0 m^2. The experiment in Grabów was carried out on the soil of a very good rye complex, and in Błonie-Topola on a very good wheat complex, class IIIa. The content of phosphorus in the soil at both experiment locations ranged from 73.7 to 78.4 g kg^{-1}, of potassium from 78.8 to 90.5 g kg^{-1}, with pH ranging from 5.8 to 6.3. The following fertilization rates were applied (kg ha^{-1}): N – 30 (ammonium sulphate), P_2O_5 – 60 (triple superphosphate), K_2O – 90 (potassium salt). Sowing was carried out at the turn of March and April. Faba beans were grown after cereals. Stomp 330 EC was used at a dose of 3.5 l ha^{-1} to control weeds in faba beans after sowing. Faba beans were harvested at full maturity, in the first decade of August. During the vegetation period, records of plant development stages were taken: full germination, beginning and end of flowering, maturity of 70–80% of seeds per plant.

Table 1. Characterization of TerrahydrogelAqua (crosslinked acrylic, potassium polymer).

Humidity	6–10%
Degree of absorption of distilled water	350–550 g/g gel
Degree of brine absorption	40–70 g/g gel
Absorption speed	0,5–2 h
Granulation	20–40 mesh
Biodegradation	3–5 years
pH	6–8
Commercial form	granulated
Registration	REACH
Price	300–310 PLN/10 kg

Source: http://www.hydrogel.pl/produkty/terra-hydrogel-aqua/

Prior to harvest, the morphological data were recorded in selected plants (the length of the fruiting part of the shoot, number of pods and seeds per plant, number of seeds in a pod, dry weight of the stem of one plant and the weight of pods). In addition, the weight of seeds per plant and the weight of one thousand seeds were determined. After harvest, the seed yield was determined at 14% moisture. The seed contents of total nitrogen and phosphorus was determined by Continuous Flow Analysis (CFA), and the content of potassium by atomic emission spectrometry. The seeds were also analyzed for crude fat, crude fibre and ash (weight method) contents.

RESULTS AND DISCUSSION

Table 2 presents the pattern of weather conditions at the RDZ Grabów and in Błonie-Topola in the years 2014–2016. In 2014 in Grabów, the sum of rainfall from March to September was by 23.5% higher than the long-term average. In 2014 and 2015, there was a large amount of rainfall in May, which made cultural practices difficult to perform. In 2015, in June, the third decade of July, and especially in August, the sum of rainfall was lower compared to the long-term average, which had a negative impact on the growth and development of faba beans. In addition, high temperatures in July and August further exacerbated the conditions for crop yields. In 2016, the rainfall was fairly evenly distributed in Grabów, and despite the fact that the sum of rainfall during the vegetation period was much lower than the long-term average, it was conducive to the high yielding of plants. In Błonie-Topola, in each study year, the sum of rainfall during the faba bean vegetation period was smaller compared to the quantities recorded in Grabów, especially the sum of rainfall in 2014. On the other hand, in Błonie-Topola in 2014, the sum of rainfall during the vegetation period was greater, and its distribution was more favourable in comparison to the other study years. In 2015 and 2016, there was a shortage of rainfall in May, June and July, which adversely affected the yield of faba beans.

The weather conditions during the vegetation period and the hydrogel used had a significant influence on the yield of faba beans in both locations (Table 3). Averaged across three years, the faba bean in the central-eastern part of Poland (Grabów) yielded better than in the central part (Błonie-Topola). In the first year, both crops recorded much higher yields than in the next two years. This was mainly caused by the more favourable weather conditions in June and July. The use of the TerrahydrogelAqua superabsorbent in the faba bean production had a positive effect on the seed yield compared to the control, where no hydrogel was used. In Grabów, for the doses of hydrogel used, the increase in seed yield was about 22% on average, and

Table 2. Weather conditions during the vegetation of faba bean.

Specification	Month							Sum
	III	IV	V	VI	VII	VIII	IX	
Grabów								
2014								
Rainfall [mm]	36.5	51.1	161.7	93.1	101.4	91.9	15.2	550.9
Temperature [°C]	3.6	9.9	13.5	15.2	20.4	17.9	14.4	
2015								
Rainfall [mm]	63.2	34.8	107.0	30.3	51.7	6.2	93.9	387.1
Temperature [°C]	3.7	7.8	13.4	16.3	18.2	17.9	13.3	
2016								
Rainfall [mm]	52.3	45.1	39.4	60.1	81.9	53.6	20.3	352.7
Temperature [°C]	3.9	9.2	14.9	18.7	19.2	18.1	15.7	
Average rainfall from the years 1871–2000	34	50	67	79	87	71	58	446
Average temperature from the years 1871–2000	2.1	8.0	13.6	16.8	18.5	17.8	13.2	
Błonie-Topola								
2014								
Rainfall [mm]	32.1	19.1	78.0	46.6	55.5	30.0	44.7	306.0
Temperature [°C]	6.6	11.0	14.5	16.2	21.5	17.9	14.9	
2015								
Rainfall [mm]	31.0	27.7	18.6	16.2	48.4	19.8	38.2	199.9
Temperature [°C]	4.9	8.2	14.7	18.2	19.8	22.2	14.4	
2016								
Rainfall [mm]	16.9	21.7	15.9	31.8	77.7	36.9	5.5	206.4
Temperature [°C]	4.1	9.7	15.4	17.9	19.5	18.5	16.9	

Table 3. Yield of faba bean seeds [t ha^{-1}] depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	4.38	1.65	1.88	2.64	2.97	1.55	0.71	1.74
10	5.01	2.24	2.11	3.12	3.30	1.96	1.32	2.19
20	5.25	2.25	2.05	3.18	3.68	1.98	1.30	2.32
30	5.77	2.29	2.01	3.36	4.26	2.08	1.87	2.74
Mean	5.10	2.11	2.01		3.55	1.89	1.30	
$HSD_{0.05}$	0.329	0.415	0.211		0.231	0.197	0.18	

in Błonie-Topola it was significantly higher and amounted to over 38%. However, increasing the dose from 10 to 30 kg ha^{-1} had a positive effect on seed yield at both locations in the wet year (2014) (in Błonie also in the dry year 2016), and in the other years, it had no significant effect on the yield. In Grabów, increasing the dose from 10 to 30 kg ha^{-1} resulted in an increase of about 7.5% in the seed yield, in Błonie-Topola in the wet year (2014) it was approx. 29%, and in the dry year (2016) the increase was over 40%. There is little information in the literature regarding the use of superabsorbents in the cultivars of coarse legumes. Owczarzak et al. (2006) state that hydrogel used in pea production under irrigation contributed to the increase of seed yield by about 23% in relation to the control. However, in non-irrigated conditions, the pea yields were on a similar level regardless of the hydrogel dose used. The results obtained by Faligowska and Szukała (2011) indicate that the use of the organic polymer Stockosorb Medium 500 did not significantly influence the yield of pea seeds. The same authors (Faligowska, Szukała, 2014) report that the use of the organic polymer did not have a significant impact on the yield of the assessed varieties of soybean. More studies were also conducted on the influence of superabsorbents on the growth and yield of various species of vegetables. Kołota and Krężel (1995) stated that the addition of Akryżel to the substrate increases the yield

Table. 4. Concentrations of nutrients in faba bean seeds [g kg^{-1}] depending on dose of hydrogel (Grabów).

Dose of hydrogel [kg ha^{-1}]	Protein	Ash	Fat	Fiber	P	K
2014						
Control	269.0	37	11	68	6.2	12.8
10	269.0	38	11	68	6.3	12.7
20	271.5	38	11	70	6.2	12.9
30	274.3	39	12	71	6.4	13.1
Mean	270.9	38	11	69	6.3	12.9
2015						
Control	297.5	40	23	65	6.3	12.0
10	291.7	40	25	63	6.2	11.6
20	291.5	39	24	65	6.0	11.7
30	293.7	41	26	67	6.3	12.0
Mean	293.6	40	24	65	6.2	11.8
2016						
Control	271.2	36	28.0	81.2	5.6	12.5
10	275.0	36	28.1	83.1	5.6	12.3
20	269.2	36	29.8	79.5	5.6	12.8
30	268.8	37	29.8	79.7	5.4	12.7
Mean	271.0	36	28.9	80.9	5.6	12.6
$HSD_{0.05}$	ns	1.25	ns	ns	ns	ns

ns – differences not significant

of fresh weight of tomato, cabbage and lettuce. Biesiada et al. (1997) confirm that the addition of superabsorbents to the soil contributes to the increase in total yield, especially the commercial yield of cabbage. Jabłońska-Ceglarek and Cholewiński (1998) observed an upward tendency in the yield of pepper after the application of Aquagel. Meanwhile, Abd El-Rehim et al. (2004) observed an increase in the dry weight of cobs, plant height and maize leaf width resulting from higher doses of hydrogel. Robiul et al. (2011) noted a significant increase in the yield of maize after the application of 30 and 40 kg ha^{-1} of hydrogel, 22.4% and 27.8%, respectively. According to these authors, in maize production, the optimal dose of a superabsorbing polymer equals 30 kg ha^{-1} because it positively influences the yield and quality of maize grains, as well as retains a high level of nutrients in the soil. The application of smaller doses (10 and 20 kg ha^{-1}) or a larger dose (over 40 kg ha^{-1}) was not economically justified. In addition, these authors suggest that the application of 30 kg ha^{-1} of hydrogel could be an effective and economical practice in the cultivation of maize in regions affected by drought. According to Kościk and Kowalczyk-Juśko (1998), on the non-watered plants, as the dose of polymer was enlarged, the yield of tobacco leaves was increased while its quality deteriorated. Moreover, according to these authors, regardless of the dose, the addition of hydrogel resulted in a significant increase in the weight and volume of roots, as well as in the height of plants, compared to the control.

The application of hydrogel, as well as increasing its dose, had a relatively small effect on the amount of protein, fat, fibre, ash, phosphorus and potassium accumulated in seeds (Table 4). Only a slightly higher concentration of ash compared to the control was noted in faba bean, where 30 kg ha^{-1} of hydrogel was applied pre-plant. In addition, in 2015 only a larger amount of protein was noted, in 2016 it was the case for fibre and in 2014 there was significantly less fat, which is difficult to explain, and was likely caused by the varying course of weather conditions during the vegetation period. According to Robiul et al. (2011), the application of 30 and 40 kg ha^{-1} of hydrogel increases the protein, sugar and starch content in maize seeds.

Changes in the features of faba bean plants under the influence of hydrogel were relatively small. The application of 30 kg ha^{-1} of hydrogel in both regions in the first two years of conducting the experiment positively influenced the weight of a thousand seeds of faba beans, whereas in 2016 the difference was significantly smaller (Table 5). In 2014 and 2015 in Grabów, the varied level of hydrogels had no significant effect on the number of pods per plant, while in 2016 a significant increase was observed after the application of hydrogel at 30 kg ha^{-1} (Table 6). In Błonie-Topola a positive effect of hydrogel was noted, and in the wet year (2014) a significant effect of increased doses was also noted. The number of seeds per pod is a feature which is subject to relatively small changes under the influence of crop management-related and environmental factors.

Table. 5. Thousand seed weight [g] of faba bean depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	478	368	403	416	476	340	358	391
10	492	374	410	425	486	357	355	399
20	496	378	398	424	511	357	360	409
30	509	385	401	432	534	361	355	417
Mean	494	376	403		502	354	357	
$HSD_{0,05}$	25.4	11.2	3.9		12.1	2.7	ns	

ns – differences not significant

Table 6. Number of pods per plant of faba bean depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	12.93	5.93	6.63	8.90	8.15	5.25	6.30	6.57
10	13.21	6.83	6.73	8.92	10.25	5.55	7.65	7.82
20	13.59	6.60	6.70	8.96	10.90	5.40	7.75	8.02
30	13.93	6.73	6.93	9.20	12.15	5.49	7.60	8.41
Mean	13.40	6.50	6.75		10.36	5.42	7.33	
$HSD_{0,05}$	ns	0.288	0.137		0.208	0.145	0.188	

ns – differences not significant

Table 7. Number of seeds per pod of faba bean depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	2.53	2.78	2.57	2.63	3.46	2.60	2.37	2.81
10	2.57	3.01	2.45	2.68	3.56	2.70	2.49	2.92
20	2.73	2.91	2.50	2.71	3.58	2.96	2.41	2.98
30	2.84	3.12	2.49	2.82	3.84	3.02	2.47	3.11
Mean	2.67	2.96	2.50		3.61	2.82	2.44	
$HSD_{0,05}$	0.143	0.117	ns		0.133	ns	ns	

ns – differences not significant

Table 8. Number of seeds per plant of faba bean depending on dose of hydrogel

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	32.8	16.4	17.65	22.28	30.55	14.00	14.90	19.82
10	33.6	20.70	16.58	23.62	35.45	15.10	19.05	23.20
20	36.9	19.30	16.73	24.31	38.70	15.20	18.65	24.18
30	39.5	21.00	17.30	25.93	46.70	15.65	18.60	26.98
Mean	35.7	19.40	17.07		37.85	14.99	17.80	
$HSD_{0,05}$	4.07	1.94	ns		3.663	ns	1.582	

ns – differences not significant

In the research conducted in Grabów, the superabsorbent applied caused a significant increase in the number of seeds per pod (2014 and 2015), and in Błonie-Topola such a tendency was observed only in the first year of research (Table 7). The seed number per plant in the east-central part of Poland in 2014, as well as in Błonie-Topola in 2014 and 2016, was higher in the superabsorbent-treated plants (Table 8). Likewise, the weight of seeds in Błonie-Topola and Grabów in 2014 was higher in hydrogel-treated plants than in the non-hydrogel control (Table 9). In addition, in Błonie-Topola in the first two years of experiment, increasing the amount of hydrogel from 10 kg ha^{-1} to 30 kg ha^{-1}

Table 9. Seed weight per plant [g] of faba bean depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	15.26	6.36	5.28	8.97	15.07	5.18	5.66	8.64
10	13.40	7.23	5.23	8.62	17.26	5.44	6.15	9.62
20	17.58	7.31	5.35	8.35	20.79	5.37	6.13	10.28
30	18.89	7.58	5.52	10.66	22.21	5.92	5.88	11.34
Mean	16.28	7.12	5.35		18.83	5.48	5.96	
$HSD_{0,05}$	2.933	ns	ns		3.285	0.328	0.078	

ns – differences not significant

Table 10. Morfology of horse bean plants depending on dose of hydrogel (Grabów).

Dose of hydrogel [kg ha^{-1}]	2014			2015			2016		
	height [cm] to:		length of the fruiting part [cm]	height [cm] to:		length of the fruiting part [cm]	height [cm] to:		length of the fruiting part [cm]
	1st pod	top		1st pod	top		1st pod	top	
Control	56	142	66	59	107	17	38	66	14
10	58	141	66	61	106	18	39	69	14
20	64	144	60	59	106	20	38	68	13
30	63	141	60	57	110	21	40	70	15
Mean	60	142	63	59	107	19			
$HSD_{0,05}$	6,2	ns	ns	ns	ns	ns			

ns – differences not significant

Table 11. Morfology of horse bean plants depending on the dose of hydrogel (Błonie-Topola).

Dose of hydrogel [kg ha^{-1}]	2014			2015			2016		
	height [cm] to:		length of the fruiting part [cm]	height [cm] to:		length of the fruiting part [cm]	height [cm] to:		length of the fruiting part [cm]
	1st pod	top		1st pod	top		1st pod	top	
Control	60	140	31	42	66	8	31	61	11
10	62	144	35	41	64	8	33	60	12
20	64	150	34	42	67	9	34	60	10
30	62	144	34	45	69	8	31	62	10
Mean	62	144	33	42	66	8.3	32	61	11
$HSD_{0,05}$	ns	6.4	ns	ns	ns	ns	ns	ns	ns

ns – differences not significant

Tabela 12. Stem dry matter [g] of plant of faba bean depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	12.6	8.3	4.05	8.32	12.19	5.39	4.33	7.30
10	14.3	8.30	3.99	8.86	12.50	5.81	5.34	7.88
20	14.9	8.90	4.01	9.27	13.82	6.90	4.55	8.42
30	15.3	9.00	4.37	9.56	14.45	7.08	4.89	8.81
Mean	14.3	8.60	4.11		13.24	6.30	4.78	
$HSD_{0,05}$	1.4	ns	ns		1.11	1.09	ns	

ns – differences not significant

Table 13. Pod dry matter [g] of faba bean plant depending on dose of hydrogel.

Dose of hydrogel [kg ha^{-1}]	Grabów				Błonie-Topola			
	2014	2015	2016	mean	2014	2015	2016	mean
Control	5.06	2.10	2.10	3.09	3.81	2.03	1.69	2.51
10	5.13	2.40	2.06	3.20	4.30	2.08	1.76	2.71
20	5.21	2.49	2.17	3.29	5.19	1.99	1.59	2.92
30	5.22	2.45	2.09	3.25	5.06	1.97	1.69	2.91
Mean	5.16	2.36	2.11		4.59	2.02	1.68	
$HSD_{0.05}$	ns	ns	ns		0.82	ns	ns	

ns – differences not significant

influenced this feature positively. The effect of the applied hydrogel on the height of the first pod setting, height of plants, length of the fruiting part, dry weight of the stem and faba bean pods was relatively small (Tables 10-13). As stated by Faligowska and Szukała (2014), the application of an organic polymer in soybean cultivars resulted in a significant increase in the number of pods per plant only in the SN 2394 line, which, however, did not affect the yield level. In the opinion of these authors the use of this polymer did not have a significant effect on the number and weight of seeds per plant, and the weight of 1000 seeds in all the assessed cultivars of this species.

CONCLUSIONS

1. The positive effect of the TerrahydrogelAqua on the yield of faba bean compared to the control, where no hydrogel was used, was noted. Increasing the dose of hydrogel from 10 kg ha^{-1} to 30 kg ha^{-1} had a positive effect on the yield of seeds in both the regions in the wet year (2014) (in Błonie also in the dry year 2016), and in the remaining years, it had no significant effect on the yield level.
2. The use of hydrogel, as well as increasing its dose had a relatively small effect on the contents of the major nutrients in faba bean seeds. A higher concentration of ash was noted in faba bean seeds from plants treated with 30 kg ha^{-1} of hydrogel.
3. The use of hydrogel in faba bean production positively influenced the weight of one thousand seeds, the number of seeds, the weight of seed and number of pods per plant, as well as the number of seeds per pod. While increasing the dose of hydrogel had no significant effect on the number of pods per plant.

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