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POTENTIAL OF HYDROGEL APPLICATION FOR PLANT PROTECTION

MOŻLIWOŚĆ ZASTOSOWANIA HYDROŻELI W OCHRONIE ROŚLIN

Abstract: Hydrogels are more and more commonly used in agriculture, among others as preparations increasing the substratum water capacity and improving the soil structure. They may be also utilized as fertilizer and pesticide carriers. The latter possibility was the subject matter of the present research. Hydrogel was used for making a biopreparation containing *Beauveria bassiana* fungus. The gel preparation was less effective at low temperatures than an insecticide, but at the temperatures of 25 and 30^o it was acting faster.

Keywords: hydrogel, *Leptinotarsa decemlineata*, insecticides, *Beauveria bassiana*

Climate changes contribute to long lasting drought periods, which are interrupted by downpours causing water runoff from fields carrying fertilizers and plant protection chemicals. One of the methods of reducing water deficit may be the application of soil supplements causing an increase in soil retention and at the same time improving the soil structure and counteracting water and air erosion. Polymer soil supplements belong to a group of such products [1, 2].

Superabsorbents (hydrogels), characterized by extensive water absorptiveness, mixed with soil, increase its water capacity [3], counteract water stresses by ensuring moisture for plants but also by reducing water evaporation from soil. They counteract rapid changes of the soil moisture by acting as a water buffer. During irrigation or rainfall they bind water preventing its seeping into deeper soil layers and surface runoff [4]. The results mentioned above are observed already at small doses of dry supersorbent mixed with the substratum in the proportion of 0.05–0.5 %. Plants are able to use over 90 % of water retained by a supersorbent. As a result of giving up water to plants it shrinks causing empty places in the soil. Owing to its ability to swell and shrink several times, it improves soil structure causing its loosening and aeration [5–9].

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Superabsorbents contribute to protection of surface waters and the environment through utilization of their ability to immobilize fertilizer components, herbicides and pesticides. Chemical compounds trapped in a polymer net cannot be fast washed out by water from rainfalls or irrigation. Small quantities of these compounds released successively may be efficiently utilized by plants or protect the plants against pests and destroy weeds.

Positive results of hydrogen applications have been registered in the mountain areas, on escarpments and embankments, where they prevent water erosion. They are widely used for degraded areas reclamation, particularly in places where vegetation which would make revegetation, bush planting or afforestation of the area possible, was completely destroyed. They are also ingredients of natural and artificial substrata used both in gardening and reclamation [10].

Among numerous applications of hydrogels one should mention their use for coating and conditioning of seeds. They not only ensure constant moisture but are also a matrix for fertilizer component and plant protection means crucial for proper seed germination and development of plants. In this way they minimize losses of seeding material and play a part in the environmental protection. Also roots of plants planted with uncovered root systems are covered with hydrogels, which prevents their overdrying and reduces the number of seeds falling out after planting.

Hydrogels are also used as pesticide carriers. Research was conducted on Horse Chestnut Leaf-miner (*Cameraria ohridella*) control using a chemical preparation in the form of a gel. Research is conducted on hydrogel application as a carrier in fungal preparations used for combating insect pests. In this case gel is a carrier of spores or mycelium depending on the application method. A gel preparation containing *Beauveria bassiana* fungus spores was, among others, used for potato beetle (*Leptinotarsa decemlineata* Say.) larvae control. Further practical applications of agrogels still require extensive research. Ratajkiewicz et al [11] researched a potential application of Agrogel as an adiuvant at the use of Prefera and Mycotal mycoinsecticides for combating greenhouse white fly (*Trialeurodes vaporariorum*). However, the authors did not observe any positive effect of the Agrogel on the efficacy of these biopreparations. Studies have been also conducted on the use of gels for *Trichoderma* antagonistic fungi application [12].

Measurements of absorption pressure inform about the thermodynamic state of water in the hydrogel. Only a minimum part of water (about 2–4 cm^3/g) is beyond the range of the water available to plants. From the biological point of view it means that most of water stored in superabsorbents is available to plants. On the other hand, Hetman and Martyn [13] found that a supplement of Akrygel and Alcosob gels dosed 250–500 g kg^{-1} of horticultural substratum, apart from increasing usable water retention, also significantly raised unavailable water retention. Słowińska-Jurkiewicz and Jaroszuk [14] proved that in the water capacity of Hidroplus hydrogel, adsorptive water – unavailable to plants or hardly available, constituted the highest proportion.

With respect to chemistry, superabsorbents are networked, water insoluble polymers, usually based on acrylamide, acrylic acid or metacrylic acid and their derivatives. Other macromolecules, such as networked polyvinyl alcohol, polyethyleneglycols, poly-

-*N*-vinylpirolidone, copolymers of maleic anhydride and chemically modified copolymers based on starch and cellulose.

Currently acrylic polymers have the widest agricultural applications. These are compounds obtained as a result of polymerization of acrylamide, acrylic acid and its water soluble potassium, sodium and ammonium salts.

Two groups of polymers may be distinguished :

– water soluble linear polymers,

– network (mostly water insoluble) polymers.

Superabsorbents belong to network, water insoluble polymers. They are obtained through polymerization of monomers with divinyl substances, which bind single chains into a network.

Also not network (linear) polymers, water soluble polymers are produced, which find applications as flocculants in chemical and extraction industry, in sewage treatment plants and for ground sealing.

Practical applications of ionic polymers include also the use of anion polymers. Anion (carboxyl) groups increase hydrogel absorptiveness. Water is bound by hydrogen bonds between protons and oxygen atoms of carboxyl groups. A nonionic polymer group is characterized by a considerably smaller absorptivity but it is more resistant to ions in water. Water fixation happens here using hydrogen bonding between nitrogen atoms or oxygen with hydrogen.

The work aimed to study the potential of superabsorbent application to use entomopathogenic fungi against crop pests.

Material and methods

A laboratory experiment was conducted to compare the efficacy of the tested fungal preparations and chemical insecticides. Two strains of entomopathogenic fungus *Beauveria bassiana* – Bb 57 and Bb 64 were used. The fungus was cultured under laboratory conditions on a modified glucose and potato medium (instead of agar a polyacrylic gel with an addition of cellucotton was used). After four weeks of culturing at the temperature of 25 ^{o}C distilled water was poured on the Petri dishes and then the spore suspension was decanted. Spore concentration in the suspension was assessed in Bürker chamber using the methods described by Lipa and Śliżyński [15]. The tested chemical insecticide was Decis 2.5 EC in the concentration of 0.083 %, which corresponds to a dose of 0.251 dm^3/ha when 300 dm^3 of usable liquid is used. In order to prepare fungal preparation water suspension of *B. bassiana* spores was mixed with an appropriate amount of polyacrylamide gel (Agroaquagel). The gel was specially prepared for application in sprayers, finely dispersed to prevent clogging fog nozzles. The gel was added to spore suspension in the dose of 0.5 g/dm^3. The dose of *B. bassiana* spores in the preparations was – $5 \times 10^5/cm^3$. The test insects were also sprayed with a spore water suspension in the same concentrations as the gel preparation used. The control insects were sprayed with distilled water.

The test insects were larvae (L_1, L_2, L_3 and L_4) and imago of potato beetle (*Leptinotarsa decemlineata* Say.). The larvae and beetles had been earlier collected on potato fields. After their supply to the laboratory they were fed with potato leaves. The experiment was conducted in Petri dishes with the 100 mm diameter. The dishes were lined with three layers of filtration paper. 10 potato beetle specimens at respective stages of development were placed in the dishes. Decis 2.5 EC and fungal preparations were applied by means of a hand sprayer. The experiment was conducted in four replications. After the spraying, the dishes with insects were put into a thermostat and kept at the temperature of 15, 20, 25 and 30 ^{o}C. The mortality of the test insects was checked every day for 7 days. The larvae and beetles were fed potato leaves throughout the experiment.

Results and discussion

Hydrogels find numerous applications in agriculture. They are, among others, applied as a supplement to substrata to increase their water capacity and prevent fast overdrying. Hydrogels are often used for establishing lawns. Recently research has been conducted on the potential use of hydrogels for establishing osier plantations for energy generation. Superabsorbents may prove useful for application of both chemical and biological preparations for plant protection. Some research focuses on gel use for making fungal preparations for crop pest combating. Results of such studies were presented below.

The mortality rate of the L_1 potato beetle treated with fungal preparations and insecticides was presented in Table 1. In the case of Decis 2.5EC insecticide high efficiency was registered at the temperatures of 15 and 20 ^{o}C. At 30 ^{o}C the preparation did not kill all potato beetle specimens during 7 days of the experiment. Lesser efficacy of fungal preparations was observed at lower temperatures, particularly when the fungus was applied as a water spore suspension. The fungal preparation with gel addition caused the death of all L_1 larvae at the temperatures of 20–30 ^{o}C. More pronounced differences in the efficiency of tested preparations were observed while analyzing the average life span of L_1larvae. The efficacy of Decis 2.5EC insecticide was very high at the temperatures of 15 and 20 ^{o}C. On the other hand at 25 ^{o}C the test insect life was considerably prolonged. A similar relationship was observed for L_2 larvae (Table 2), L_3 (Table 3), L_4 (Table 4) and potato beetle imago (Table 5). Diminishing efficiency of synthetic pyretroids at the temperatures above 20 ^{o}C is well known. The instructions for the use of this preparation clearly recommend its application at temperatures below 20 ^{o}C. There are preparations whose activity does not depend on the ambient temperature, eg Actara, but pyretroids are still among the most commonly used plant protection means. However, fungal preparations were far more efficient at higher temperatures than at lower ones. If at the temperatures of 15 and 20 ^{o}C the insecticide killed the test insects 3–5 times faster than fungal preparations, at 30 ^{o}C it acted more slowly than fungal preparations. A comparison of the effect of *B. bassiana* spore water suspension and gel preparation containing fungus spore showed a better efficacy of the gel preparation in killing larvae and imago of potato beetles. The chemical preparation effectively combated potato beetles at all tested stages of development. Similar fungal preparations affected both the larval and imago stages. In the case of potato beetles younger larval stages should be controlled before the beetle causes considerable yield losses. The beetles may be also combated at the moment of their invasion on a potato

Table 1

Mortality rate of potato beetle L_1 larvae treated with fungal preparation containing *B. bassiana* fungus spore

Temperature [°C]	Preparation					
	Control	Decis 2,5 EC	Fungus strain			
			Bb 57		Bb 64	
			Water suspension	Gel preparation	Water suspension	Gel preparation
Test insect mortality rate [%]						
15	0.0 a*	100.0 e	75.0 b	85.0 c	77.5 b	90.0 cd
20	0.0 a	100.0 e	77.5 b	100.0 e	95.0 de	100.0 e
25	0.0 a	100.0 e	100.0 e	100.0 e	100.0 e	100.0 e
30	0.0 a	100.0 e	95.0 de	100.0 e	100.0 e	100.0 e
Average life span of test insects [days]						
15	7.0 l	1.0 a	5.4 k	4.3 i	5.35 k	4.45 i
20	7.0 l	1.0 a	4.68 j	3.1 f	4.0 h	3.35 g
25	7.0 l	2.85 de	3.05 ef	2.03 b	2.8 d	2.05 bc
30	7.0 l	4.73 j	3.9 h	2.0 b	3.2 fg	2.25 c

* means marked with the same letter do not differ significantly at p = 0.05

Table 2

Mortality rate of potato beetle L_2 larvae treated with fungal preparation containing *B. bassiana* fungus spore

Temperature [°C]	Preparation					
	Control	Decis 2,5 EC	Control			
			Bb 57		Bb 64	
			Water suspension	Gel preparation	Water suspension	Gel preparation
Test insect mortality rate [%]						
15	0.0 a*	100.0 g	67.5 b	95.0 f	75.0 c	100.0 g
20	0.0 a	100.0 g	82.5 d	100.0 g	87.5 e	100.0 g
25	0.0 a	100.0 g	100.0 g	100.0 g	100.0 g	100.0 g
30	0.0 a	100.0 g		100.0 g	100.0 g	100.0 g
Average life span of test insects [days]						
15	7.0 j	1.0 a	5.6 i	4.1 g	5.45 i	4.1 g
20	7.0 j	1.0 a	4.2 g	3.0 d	4.2 g	3.25 e
25	7.0 j	2.75 c	2.9 cd	2.2 b	2.7 c	2.3 b
30	7.0 j	4.65 h	3.5 f	2.85 cd	3.4 ef	2.4 b

* means marked with the same letter do not differ significantly at p = 0.05

Table 3

Mortality rate of potato beetle L_3 larvae treated with fungal preparation containing *B. bassiana* fungus spore

Temperature [°C]	Preparation					
	Control	Decis 2,5 EC	Fungus strain			
			Bb 57		Bb 64	
			Water suspension	Gel preparation	Water suspension	Gel preparation
Test insect mortality rate [%]						
15	0,0 a*	100.0 g	65.0 b	90.0 ef	67.5 b	95.0 fg
20	0,0 a	100.0 g	85.0 de	100.0 g	82.5 cd	100.0 g
25	0,0 a	100.0 g	100.0 g	100.0 g	100.0 g	100.0 g
30	0,0 a	77.5 c	85.0 de	100.0 g	100.0 g	100.0 g
Average life span of test insects [days]						
15	7,0 l	1.0 a	5.65 k	4.25 hi	5.6 k	4.25 hi
20	7,0 l	1.0 a	4.05 gh	3.0 de	4.38 i	3.25 ef
25	7,0 l	2.83 cd	2.9 cd	2.2 b	2.7 c	2.3 b
30	7,0 l	4.68 j	3.9 g	2.85 cd	3.4 f	2.4 b

* means marked with the same letter do not differ significantly at p = 0.05

Table 4

Mortality rate of potato beetle L_4 larvae treated with fungal preparation containing *B. bassiana* fungus spore

Temperature [°C]	Preparation					
	Control	Decis 2,5 EC	Fungus strain			
			Bb 57		Bb 64	
			Water suspension	Gel preparation	Water suspension	Gel preparation
Test insect mortality rate [%]						
15	0,0 a*	100.0 e	70.0 b	97.5 e	80.0 c	100.0 e
20	0,0 a	100.0 e	82.5 cd	100.0 e	87.5 d	100.0 e
25	0,0 a	100.0 e	100.0 e	100.0 e	100.0 e	100.0 e
30	0,0 a	80.0 c	85.0 cd	100.0 e	97.5 e	100.0 e
Average life span of test insects [days]						
15	7,0 l	1.0 a	5.55 k	4.55 i	4.95 j	4.1 gh
20	7,0 l	1.0 a	4.2 h	3.5 f	3.95 g	3.25 e
25	7,0 l	2.75 cd	2.9 cd	2.2 b	2.7 c	2.3 b
30	7,0 l	4.58 i	3.9 g	2.98 d	3.4 ef	2.4 b

* means marked with the same letter do not differ significantly at p = 0.05

Table 5

Mortality rate of potato beetle imago treated with fungal preparation containing *B. bassiana* fungus spore

Temperature [^{o}C]	Preparation					
	Control	Decis 2,5 EC	Fungus strain			
			Bb 57		Bb 64	
			Water suspension	Gel preparation	Water suspension	Gel preparation
Test insect moratlity rate [%]						
15	0,0 a*	100.0 g	60.0 b	97.5 fg	70.0 c	100.0 g
20	0,0 a	100.0 g	85.0 g	100.0 g	90.0 de	100.0 g
25	0,0 a	100.0 g	100.0 g	100.0 g	100.0 g	100.0 g
30	0,0 a	85.0 d	92.5 ef	100.0 g	100.0 g	100.0 g
Average life span of test insects [days]						
15	7,0 k	1.0 a	5.75 j	4.0 h	5.55 j	4.1 h
20	7,0 k	1.0 a	4.13 h	3.0 de	4.1 h	3.25 ef
25	7,0 k	2.85 cd	2.9 cd	2.2 b	2.7 c	2.3 h
30	7,0 k	4.43 i	3.65 g	2.85 cd	3.4 fg	2.4 b

* means marked with the same letter do not differ significantly at $p = 0.05$

plantation. Studies on agrogel application have been also undertaken in other research centres. Ratajkiewicz et al [11] used agrogel dosed 0.4 % as an adiuvant at mycoinsecticides Preferal and Mycotal application for greenhouse white fly combating. Research conducted by these authors did not corroborate a positive effect of agrogel addition to biopreapartion on their efficacy. It shows the necessity for further research aimed at developing of both the technique of hydrogel application and new hydrogels.

The potato beetle remains one of the most serious potato pests [16], therefore seeking new methods of its combating is fully justified. According to Pruszyński and Węgorek [17] chemical protection plays and will play the main role in potato beetle control. However, the obtained results point to potential practical application of fungal preparations for this pest combating.

Conclusions

1. The efficacy of synthetic Decis 2.5EC insecticide preparation is much stronger than *B. bassiana* fungal preparations at the temperatures of 15 and 20 ^{o}C.
2. At the temperatures of 25 and 30 ^{o}C *B. bassiana* fungal preparations revealed better efficiency in killing potato beetle.
3. Gel formula of the fungal preparation was more efficacious in comparison with *B. bassiana* spore water suspension.

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MOŻLIWOŚĆ ZASTOSOWANIA HYDROŻELI W OCHRONIE ROŚLIN

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Abstrakt: Hydrożele są coraz powszechniej stosowane w rolnictwie m.in. jako preparaty zwiększające pojemność wodną podłoża i poprawiające strukturę gleby. Można je również wykorzystywać jako nośnik nawozów i pestycydów. Ta ostatnia możliwość była przedmiotem niniejszych badań. Hydrożel wykorzystano do przygotowania biopreparatu zawierającego grzyba *Beauveria bassiana*. Preparat żelowy był w niskich temperaturach mniej skuteczny niż insektycyd, ale w temperaturach 25 i 30 °C działał szybciej.

Słowa kluczowe: hydrożel, *Leptinotarsa decemlineata*, insektycydy, *Beauveria bassiana*