

## INFLUENCE OF SEAWEED EXTRACTS AND MIXTURE OF HUMIC AND FULVIC ACIDS ON GERMINATION AND GROWTH OF *Zea mays* L.

Kinga Matysiak, Sylwia Kaczmarek, Roman Krawczyk

Institute of Plant Protection – National Research Institute in Poznań

**Abstract.** Glasshouse and laboratory experiments were conducted during 2009-2010 in the Institute of Plant Protection in Poznań. The aim of these trials was to determine an influence of seaweed extracts (*Ecklonia maxima* and *Saragassum* spp.) and a humic (12%) and fulvic (6%) acids mixture on the germination, early growth and development of maize depending on the method of application. Trials involved soaking of seeds in aqueous solution of seaweed extracts and humic substances, soaking seeds and then foliar application and finally, two foliar applications. Foliar applications were done at growth stages BBCH 12-13 and 14-16. Experiments involved seed germination, chlorophyll content and fresh weight of shoots and roots. Results shows different action of tested substances on maize depending of application method. Seaweed extracts stronger induced seed germination than humic substances. Joint seed and foliar application and double foliar application promote shoot and root growth.

**Key words:** chlorophyll content, foliar application, fulvic acids, humic acids, maize, seaweed extracts, seed germination

### INTRODUCTION

In recent years a growing interest has been observed with natural biostimulating substances. The group of leading biological factors showing a favourable effect on field crops include seaweeds. Seaweeds constitute the most essential live organisms used on a wide scale commercially, and extracts from seaweeds are commonly called seaweed liquid fertiliser (SLF) [Bai et al. 2007]. A positive effect of several species of algae (*Ascophyllum* spp., *Laminaria* spp., *Ecklonia* sp.) on the growth, development and, consequently, yields of field crops has been proved so far. Seaweeds constitute a source of many substances, valuable from the point of view of plant physiology, which particularly help plants adapt to stressful conditions. Biologically active alginic acids, polyphenols, free amino acids, and particularly natural plant phytohormones:

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Corresponding author – Adres do korespondencji: dr Kinga Matysiak, Department Weed Science and Plant Protection Techniques of Institute of Plant Protection – National Research Institute in Poznań, W. Węgorza 20, 60-318 Poznań, e-mail: ior.poznan.kinga@gmail.com

auxins, cytokinins, intensify plant growth, increase the root weight, stimulate production of photosynthetic dyes, thus growing plant vitality [Blunden and Wilgoose 1977, Verkleij 1992, Csizinszky 1994, Reitz and Trumble 1996, Sultana et al. 2005]. In some works the authors particularly stress the importance of cytokinins contained in seaweeds in creating plant resistance to diseases and nematodes [Van Staden 1985, De Waele et al. 1988, Bai et al. 2007].

Humic and fulvic acids, deriving from coal or soil, exhibit the action similar to extracts from seaweeds, although a bigger importance in the development of the plant root system are ascribed to them. Humic acids are considered to be compounds increasing permeability of cellular membranes in plants [Kaya et al. 2005], and recent studies prove that these substances significantly affect an increase in seed germination energy, the intensification of seedling growth, the growth in root weight and shoot development [Katkat et al. 2009]. The effect of humic and fulvic acids on limiting the development of some pathogens is also known, e.g. *Fusarium* spp. [Yigit and Dikilitaş 2008].

Literature reports show a varied effect of extracts from seaweeds and humic and fulvic acids on field crops. Apart from the genotypic factor of the field crop and general environmental conditions, a large importance in their activity is attributed to the methods and frequency of their application [Reitz and Trumble 1996].

The aim of this study was to evaluate the action of various application methods of extracts from seaweeds *Ecklonia maxima* and *Saragassum* spp. And a mixture of humic and fulvic acids on germination, shoot and root weight, and the content of chlorophyll in leaves of maize *Zea mays* L. The working hypothesis assumed that the action of extracts from seaweeds, humic and fulvic acids on maize growth is closely dependent on the way of their application.

## MATERIAL AND METHODS

During 2009-2010 in the Institute of Plant Protection 4 cycles of laboratory and glasshouse experiments were conducted, which aimed at assessing the action of extracts from seaweeds and humic and fulvic acids on the germination and initial growth of maize. The fodder cultivar Boruta, chosen for the experiments, was characterized by a very good early vitality. The experiment involved the application of extracts from the seaweeds *Ecklonia maxima* (Kelpak SL), *Saragassum* spp. (AlgaminoPlant) and a mixture of humic acids (12%) and fulvic acids (6%) along with microelements (HumiPlant).

### Laboratory experiments

Maize seeds were placed on Petri dishes with a diameter of 18 cm, on filtration paper, 10 seeds on each. Maize seeds were previously soaked for 24 h in solutions of the tested preparations. Solutions were prepared acc. to the following scheme: 200 cm<sup>3</sup> H<sub>2</sub>O + 3 cm<sup>3</sup> Kelpak SL, 200 cm<sup>3</sup> H<sub>2</sub>O + 2 cm<sup>3</sup> Kelpak SL, 200 cm<sup>3</sup> H<sub>2</sub>O + 1.5 cm<sup>3</sup> Kelpak SL, 200 cm<sup>3</sup> H<sub>2</sub>O + 1 cm<sup>3</sup> AlgaminoPlant, 200 cm<sup>3</sup> H<sub>2</sub>O + 0.5 cm<sup>3</sup> AlgaminoPlant, 200 cm<sup>3</sup> H<sub>2</sub>O + 1 cm<sup>3</sup> HumiPlant, 200 cm<sup>3</sup> H<sub>2</sub>O + 0.5 cm<sup>3</sup> HumiPlant. On 10<sup>th</sup> day from placing the seeds, their germination capacity was assessed. The study was conducted at 20°C. 3 series of experiments in 4 replications were made.

## Glasshouse experiments

The experiments were carried out in 2 series and 4 replications. The first type of the experiments was conducted using seeds soaked in water solutions of the preparations with seeds soaked in aqueous solutions of the preparations Kelpak, HumiPlant and AlgaminoPlant. After 24 h of soaking, the seeds were sown into plastic pots in the amount of 10 pieces. per pot. After seed germination, the plants were thinned, leaving 5 plants per pot. Temperature conditions during seed germinations were within the range 24-25°C. Half of the pots were left for further observations of the plant growth, whereas the other half was treated at the stage of 2-3 maize leaves (BBCH 12-13; time T1), with the preparations Kelpak SL, AlgaminoPlant and HumiPlant. The preparations were used in the following doses: Kelpak SL: 3.0 dm<sup>3</sup>·ha<sup>-1</sup>, 2.0 dm<sup>3</sup>·ha<sup>-1</sup> and 1.5 dm<sup>3</sup>·ha<sup>-1</sup>, AlgaminoPlant: 1.0 dm<sup>3</sup>·ha<sup>-1</sup> and 0.5 dm<sup>3</sup>·ha<sup>-1</sup> and HumiPlant 1.0 dm<sup>3</sup>·ha<sup>-1</sup> and 0.5 dm<sup>3</sup>·ha<sup>-1</sup>. Seeds not soaked with solutions of the tested substances were sown separately. After seed germinations, the plants were thinned, leaving 5 plants in each pot. Then the plants were sprayed twice : at the phases BBCH 12-13 (time T1) and BBCH 14-16 (time T2). The preparations were applied in the following doses: Kelpak SL: 3.0 dm<sup>3</sup>·ha<sup>-1</sup>, 2.0 dm<sup>3</sup>·ha<sup>-1</sup> and 1.5 dm<sup>3</sup>·ha<sup>-1</sup>; AlgaminoPlant: 1.0 dm<sup>3</sup>·ha<sup>-1</sup> and 0.5 dm<sup>3</sup>·ha<sup>-1</sup> and HumiPlant: 1.0 dm<sup>3</sup>·ha<sup>-1</sup> and 0.5 dm<sup>3</sup>·ha<sup>-1</sup>. Sprayings were made with a glasshouse sprayer, adjusting the tested doses of preparations to a volume of 200 dm<sup>3</sup> of water.

Two weeks after the operation T2 the chlorophyll content was assessed using the apparatus N-tester and the SPAD method. N-tester calculates chlorophyll content on the basis of 30 properly made measurements of the given sample. The results are shown in the form of the so-called SPAD units (Soil Plant Analysis Development). The reading ranges between 0 and 800.

For weeks after T2 the aboveground parts of plants were cut and weighed. Then the weighing analysis was made of maize roots, with soil rinsed off previously. On the basis of the obtained results of chlorophyll content, fresh weight of the aboveground part of plants and root weight, their percentage increase or reduction was calculated, in comparison to the control. A growth or reduction in the values of the tested traits were determined assuming the values obtained from the control as 100%. The results of the study were calculated statistically using the analysis of variance at the significance level  $P = 0.05$ . The statistical calculations were made using the program FR-ANALWAR-4,3.

## RESULTS

### Seed germination

The effect of preparations containing seaweeds and humic and fulvic acids on germination, the content of chlorophyll in leaves, and shoot and root weight depended on the method of their application (Table 1). Extracts from seaweeds (Kelpak SL and AlgaminoPlant) stimulated plant germination more than humic and fulvic acids (HumiPlant) (Table 1). The preparation Kelpak SL increased maize seed germination by 16-19%, depending on the applied dose, the preparation AlgaminoPlant by 10-19%, and the preparation HumiPlant by 9%.

Table 1. Germination capacity of maize seeds treated with seaweed extracts and humic and fulvic acids

Tabela 1. Zdolność kiełkowania nasion kukurydzy traktowanych wyciągami z alg oraz kwasami huminowymi i fulwowymi

Treatment Obiekt	Amount of preparation in 200 cm <sup>3</sup> H <sub>2</sub> O Ilość preparatu w 200 cm <sup>3</sup> H <sub>2</sub> O	Germination capacity Zdolność kiełkowania %	Change to control Zmiana w stosunku do kontroli %
Control – Kontrola	–	80	–
Kelpak SL	3 cm <sup>3</sup>	95*	+19
Kelpak SL	2 cm <sup>3</sup>	93*	+16
Kelpak SL	1.5 cm <sup>3</sup>	93*	+16
AlgaminoPlant	1 cm <sup>3</sup>	88	+10
AlgaminoPlant	0.5 cm <sup>3</sup>	95*	+19
HumiPlant	1 cm <sup>3</sup>	87	+9
HumiPlant	0.5 cm <sup>3</sup>	87	+9
LSD <sub>0.05</sub> – NIR <sub>0.05</sub>		9.38	–

\* significant differences – różnice istotne

### Shoot and root weight of plants obtained from seeds soaked in solutions of the preparations

Of plants obtained from seeds soaked in solutions of the tested preparations, the plants subjected to the action of an extract from *Ecklonia maxima* were characterized by the largest shoot weight (Kelpak SL) (Table 2). Nevertheless, no statistically significant differences were found between the doses of the preparation and the obtained growth in shoot fresh weight ranged from 25 to 34%, as compared with the control. The preparation based on seaweeds of the genus *Saragassum* sp. (AlgaminoPlant) increased maize shoot weight by 8-11%. Plants obtained from the soaked seeds showed the weakest effect on the preparation containing humic and fulvic acids. No significant differences were found in maize shoot weight between a lower dose of the preparation AlgaminoPlant (0.5 cm<sup>3</sup>) as well as both doses of the preparation HumiPlant, and the control. Analysing the root weight of plants obtained from soaked seeds, no statistically significant differences were found for this trait, although a tendency to increasing the value of this trait after the application of extracts from seaweeds and humic acids is worth noting.

Table 2. Weight of shoots and weight of roots (seeds soaked in seaweed extracts)  
Tabela 2. Masa pędów i masa korzeni (nasiona moczone w roztworach substancji)

Treatment Obiekt	Amount of preparation in 200 cm <sup>3</sup> H <sub>2</sub> O w 200 cm <sup>3</sup> H <sub>2</sub> O	Weight of shoots Masa pędów g	Change to control Zmiana w stosunku do kontroli %	Weight of roots Masa korzeni g	Change to control Zmiana w stosunku do kontroli %
Control – Kontrola	–	195	–	93	–
Kelpak SL	3 cm <sup>3</sup>	261*	+34	106	+14
Kelpak SL	2 cm <sup>3</sup>	252*	+29	102	+10
Kelpak SL	1.5 cm <sup>3</sup>	243*	+25	98	+5
AlgaminoPlant	1 cm <sup>3</sup>	216*	+11	101	+9
AlgaminoPlant	0.5 cm <sup>3</sup>	210	+8	100	+8
HumiPlant	1 cm <sup>3</sup>	192	-2	99	+6
HumiPlant	0.5 cm <sup>3</sup>	204	+5	97	+4
LSD <sub>0,05</sub> – NIR <sub>0,05</sub>		20.5	–	ns – ni	–

\* significant differences – różnice istotne

ns – ni – non-significant difference – różnice nieistotne

### Shoot and root weight of plants obtained from seeds soaked in solutions of the preparations and sprayed once (T1 - BBCH 12-13)

All the tested preparations showed a favourable effect on a growth in shoot and root weight of plants obtained from seeds soaked in solutions of the tested substances and additionally sprayed (Table 3). The highest shoot weight was obtained in the combination with AlgaminoPlant (1.0 cm<sup>3</sup> + 1 dm<sup>3</sup>·ha<sup>-1</sup>) – by 25% higher than the control value. A lower dose of the preparation AlgaminoPlant increased the shoot weight by 21% and the same value was obtained for the highest dose of Kelpak SL (3.0 cm<sup>3</sup> + 3 dm<sup>3</sup>·ha<sup>-1</sup>). A growth in the aboveground part weight of maize was reduced along with a reduction in a dose of the preparation Kelpak SL. After the application of the preparation in a dose of 2.0 cm<sup>3</sup> + 2 dm<sup>3</sup>·ha<sup>-1</sup> and 1.5 cm<sup>3</sup> + 1.5 dm<sup>3</sup>·ha<sup>-1</sup> a growth in plant aboveground weight of 15% and 11% was obtained, respectively. The action of the preparation HumiPlant resulted in an increase of maize shoot weight by 19% at the dose 1.0 cm<sup>3</sup> + 1 dm<sup>3</sup>·ha<sup>-1</sup> and by 13% at the dose 0.5 cm<sup>3</sup> + 0.5 dm<sup>3</sup>·ha<sup>-1</sup>.

At the same time, the highest weight of plant roots was obtained in the combinations with the use of humic substances. A growth in root weight was 64-69%, depending on the dose applied. Preparations containing extracts from seaweeds also stimulated the development of maize root system, increasing its weight by 31%, 47% and 46% after the application of the preparation Kelpak at doses of 1.5 cm<sup>3</sup> + 1.5 dm<sup>3</sup>·ha<sup>-1</sup>, 2.0 cm<sup>3</sup> + 2.0 dm<sup>3</sup>·ha<sup>-1</sup> and 2.0 cm<sup>3</sup> + 2.0 dm<sup>3</sup>·ha<sup>-1</sup>, respectively. For the preparation AlgaminoPlant, a growth in the root weight by 48% (0.5 cm<sup>3</sup> + 0.5 dm<sup>3</sup>·ha<sup>-1</sup>) and 59% (1.0 cm<sup>3</sup> + 1.0 dm<sup>3</sup>·ha<sup>-1</sup>) was obtained.

### Shoot and root weight of plants after two foliar applications (T1 - BBCH 12-13 + T2 - BBCH 14-16)

Of the tested variants of application, two foliar applications of the tested preparations had the most favourable effect on the plants (Table 4). All the experimental combinations were characterized by plants with considerably larger shoots, as compared with the control. The most favourable effect on maize shoot weight after two foliar

spraying was shown by the preparation containing the algae *Saragassum* sp. (AlgaminoPlant). Depending on the dose applied, an increase in maize shoot weight by 48-50% was obtained. However, no statistically significant differences were observed between doses of the preparation both for shoot and root weight. AlgaminoPlant increased the root weight of maize by 54-57%. HumiPlant had the most favourable effect on roots. In the combination HumiPlant  $1.0 \text{ dm}^3 \cdot \text{ha}^{-1} + 1.0 \text{ dm}^3 \cdot \text{ha}^{-1}$  a 68% increase in plant root weight was obtained, achieving at the same time a growth in plant aboveground weight by 32%. For a lower dose of the humic preparation ( $0.5 \text{ dm}^3 \cdot \text{ha}^{-1} + 0.5 \text{ dm}^3 \cdot \text{ha}^{-1}$ ) an increase of 49% in root weight and of 40% in shoot weight was obtained. After two applications of the preparation Kelpak, an increase of 40% in root weight was obtained at a dose of  $1.5 \text{ dm}^3 \cdot \text{ha}^{-1}$  (T1) +  $1.5 \text{ dm}^3 \cdot \text{ha}^{-1}$  (T2), of 34% at a dose of  $2.0 \text{ dm}^3 \cdot \text{ha}^{-1}$  (T1) +  $2 \text{ dm}^3 \cdot \text{ha}^{-1}$  (T2) and of 45% at a dose of  $3.0 \text{ dm}^3 \cdot \text{ha}^{-1}$  (T1) +  $3.0 \text{ dm}^3 \cdot \text{ha}^{-1}$  (T2). In these experimental combinations, the growth in maize shoot weight accounted for, respectively, 42% for the lowest dose, 37% for the medium dose and 40% for the highest dose.

### Chlorophyll content in leaves

No differences were observed in chlorophyll content in leaves of plants obtained from seeds soaked in the solutions of the tested substances between particular experimental combinations (Table 5).

In the variant involving soaking seeds and then spraying obtained plants with solutions of the tested preparations, a statistically significant growth in chlorophyll content, in relation to the control, occurred only in the combinations where Kelpak SL was applied in doses:  $3.0 \text{ cm}^3 + 3.0 \text{ dm}^3 \cdot \text{ha}^{-1}$  and  $2.0 \text{ cm}^3 + 2.0 \text{ dm}^3 \cdot \text{ha}^{-1}$ , and a growth in dye content amounted to 9-10%.

With two foliar applications, all the preparation stimulated the synthesis of chlorophyll in maize leaves. The strongest action for this trait was indicated in AlgaminoPlant, increasing the dye content by 38-40%. No statistically significant differences were obtained in the effectiveness of particular doses of the preparation Kelpak SL, which increased the amount of chlorophyll by 27-30%. Preparation containing humic and fulvic acids increased chlorophyll content by 22% ( $1.0 \text{ dm}^3 \cdot \text{ha}^{-1} + 1.0 \text{ dm}^3 \cdot \text{ha}^{-1}$ ) and 30% ( $0.5 \text{ dm}^3 \cdot \text{ha}^{-1} + 0.5 \text{ dm}^3 \cdot \text{ha}^{-1}$ ).

## DISCUSSION

A stimulating effect of extracts from seaweeds on seed germination was proved in this experiment. The results are in accordance with the reports of Nedumaran and Perumal [1991], indicating the relation of plant hormones contained in seaweeds with the germination energy of plant seeds subjected to their action. The study conducted in the Institute of Plant Protection show the possibility of improving the germination capacity of maize seeds by 10-19% through previous soaking them in extracts from seaweeds. In the study by Jothinayagi and Anbazhagan [2009] seed germination increased along with a growth in the concentration of solutions from seaweeds. Also reports appear in the literature about the inhibiting effect of extracts from seaweeds (of the genera *Laminaria hyperborea* and *Ascophyllum nodosum*) on seed germination [Taylor et al. 1990, Moller and Smith 1998].

Table 3. Weight of shoots and weight of roots (seeds soaked in seaweed extracts + foliar application)  
 Tabela 3. Masa pędów i masa korzeni (nasiona moczone w roztworach substancji + aplikacja nalistna)

Treatment Obiekt	Soaked seeds Nasiona moczone		Foliar application Aplikacja nalistna		Weight of shoots Masa pędów g	Change to control Zmiana w stosunku do kontroli %	Weight of roots Masa korzeni g	Change to control Zmiana w stosunku do kontroli %
	amount of preparation in 200 cm <sup>3</sup> H <sub>2</sub> O – ilość preparatu w 200 cm <sup>3</sup> H <sub>2</sub> O	dose per ha dawka preparatu na ha						
Control H <sub>2</sub> O Kontrola H <sub>2</sub> O	–	–	–	–	216	–	61	–
Kelpak SL	3 cm <sup>3</sup>	3 dm <sup>3</sup>			261*	+21	98*	+46
Kelpak SL	2 cm <sup>3</sup>	2 dm <sup>3</sup>			249*	+15	99*	+47
Kelpak SL	1.5 cm <sup>3</sup>	1.5 dm <sup>3</sup>			240*	+11	86*	+31
AlgaminoPlant	1 cm <sup>3</sup>	1 dm <sup>3</sup>			270*	+25	109*	+59
AlgaminoPlant	0.5 cm <sup>3</sup>	0.5 dm <sup>3</sup>			261*	+21	100*	+48
HumiPlant	1 cm <sup>3</sup>	1 dm <sup>3</sup>			258*	+19	113*	+64
HumiPlant	0.5 cm <sup>3</sup>	0.5 dm <sup>3</sup>			243*	+13	117*	+69
					22.7	–	12.7	–

LSD<sub>0,05</sub> – NIR<sub>0,05</sub>

\* significant differences – różnice istotne

Table 4. Weight of shoots and weight of roots (foliar application + foliar application)  
 Tabela 4. Masa pędów i masa korzeni (aplikacja nalistna + aplikacja nalistna)

Treatment Obiekt	Foliar application Aplikacja nalistna		Foliar application Aplikacja nalistna II	Weight of shoots Masa pędów g	Change to control Zmiana w stosunku do kontroli %	Weight of roots Masa korzeni g	Change to control Zmiana w stosunku do kontroli %
	I	dose per ha dawka na ha					
Control Kontrola	–	–	–	180	–	62	–
Kelpak SL	3 dm <sup>3</sup>	–	3 dm <sup>3</sup>	252*	+40	103*	+45
Kelpak SL	2 dm <sup>3</sup>	–	2 dm <sup>3</sup>	246*	+37	94*	+34
Kelpak SL	1.5 dm <sup>3</sup>	–	1.5 dm <sup>3</sup>	255*	+42	99*	+40
Algaminoplant	1 dm <sup>3</sup>	–	1 dm <sup>3</sup>	267*	+48	114*	+57
Algaminoplant	0.5 dm <sup>3</sup>	–	0.5 dm <sup>3</sup>	270*	+50	112*	+54
HumiPlant	1 dm <sup>3</sup>	–	1 dm <sup>3</sup>	237*	+32	125*	+68
HumiPlant	0.5 dm <sup>3</sup>	–	0.5 dm <sup>3</sup>	252*	+40	107*	+49
LSD <sub>0.05</sub> – NIR <sub>0.05</sub>				24.6	–	10.7	–

\* significant differences – różnice istotne

Table 5. Chlorophyll content in plants obtained from seeds soaked in tested preparations and in plants after foliar application  
 Tabela 5. Zawartość chlorofilu w liściach roślin uzyskanych z nasion moczonych w badanych preparatach oraz roślin po zabiegach nalistnych

Treatment Obiekt	Dose Dawka	Soaked seeds Nasiona moczone		Soaked seeds + foliar application Nasiona moczone + aplikacja nalistna		Foliar application + Foliar application Aplikacja nalistna + aplikacja nalistna	
		chlorophyll content poziom chlorofilu (SPAD)	change to control zmiana w stosunku do kontroli %	chlorophyll content poziom chlorofilu (SPAD)	change to control zmiana w stosunku do kontroli %	chlorophyll content poziom chlorofilu (SPAD)	change to control zmiana w stosunku do kontroli %
Control Kontrola	–	477	–	498	–	498	–
Kelpak SL	3 dm <sup>3</sup>	465	-3	543*	+9	645*	+30
Kelpak SL	2 dm <sup>3</sup>	462	-3	549*	+10	634*	+27
Kelpak SL	1.5 cm <sup>3</sup>	472	-1	528	+6	657*	+32
Algaminoplant	1 cm <sup>3</sup>	482	+1	520	+4	687*	+38
Algaminoplant	0.5 cm <sup>3</sup>	473	-1	512	+3	694*	+40
HumiPlant	1 cm <sup>3</sup>	488	+2	486	-2	611*	+22
HumiPlant	0.5 cm <sup>3</sup>	469	-2	494	-1	645*	+30
LSD <sub>0.05</sub> – NIR <sub>0.05</sub>		31.5	–	35.4	–	41.5	–

\* significant differences – różnice istotne

The literature data describing the action of extracts from seaweeds on field crops are not consistent and refer to examples of both stimulating and inhibiting effect of seaweeds on the growth and development of plants. De Waele et al. [1988], in glasshouse experiments did not obtain a significant effect of seaweeds on plant growth and development. However, the results obtained in the presented study indicates a favourable effect of extracts from seaweeds and humic substances on the initial growth and development of maize. Bai et al. [2007], as a result of foliar application of extracts from seaweeds on field crops obtained shoots longer by 35%, and roots longer by 22%, in comparison with the control. Similar results were obtained by De Villiers et al. [1983] and Thevanathan et al. [2005] in their studies over the effect of seaweeds on the growth and development of maize. In the study conducted in the Institute of Plant Protection, it was proved that foliar application of extracts from seaweeds strongly stimulates the development of shoots and roots of maize. Using the variant of the two foliar applications of an extract from the brown alga *Ecklonia maxima* it is possible to obtain a growth in plant shoot weight by 37-42% and root weight by 34-45%, and with an extract from the brown alga *Saragassum* spp. respectively by 48-50% and 54-57%.

Some authors stress the existence of a strong relation between the dose of seaweed solution and their effectiveness. Nedumaran and Perumal [2009] obtained the highest growth of shoot and root weight applying seaweeds in low doses. This assumption is confirmed in the study by Jeannin et al. [1991], who using an extract from seaweeds in smaller doses, obtained a growth in the weight of maize seedlings by only 15-25%, in relation to the control. The studies carried out in the Institute of Plant Protection show that apart from the concentration of seaweed-based preparations, the method and frequency of their application is of a significant importance for changes in maize plant weight.

A positive effect of humic acids on plant growth is confirmed in the study by Ferrara et al. [2007], as well of humic acids in the study by Xu [1986]. The authors' research presented in this work proves that stimulation of maize growth is possible after the application of humic and fulvic acids. A favourable effect of these compounds can be mostly observed in the stimulation of the plant root system, and consequently, a growth in its weight even by 60%. A similar growth in the root weight after the application of humic acids was obtained by Arancon et al. [2006]. According to Sarir et al. [2005], using humic acids it is possible to obtain a growth in green weight of field crops even by 28%. In the authors' study, the effect of humic and fulvic acids on maize shoot weight was obtained after two foliar applications, and the shoot weight increased even by 40%.

The research carried out in the Institute of Plant Protection indicates that chlorophyll content in plant leaves can be increased, resulting from using extracts from algae, humic and fulvic acids, but the process of the dye synthesis is closely dependent on the way of application of the mentioned substances. In the experiments conducted there were no changes in the dye content after soaking seeds in solutions of extracts from seaweeds and humic and fulvic acids. A slight effect on this trait was obtained in the variant of soaking seeds and an additional foliar application of seaweed extracts. The strongest effect on the synthesis of chlorophyll was obtained after two foliar applications both with extracts from seaweeds and humic and fulvic acids. An increase in chlorophyll content in leaves after the application of extracts from seaweeds was obtained by Blunden et al. [1996], whereas a negative effect on this trait was recorded by Venkataraman Kumar and Mohan [1997]. A positive effect of humic acids on

chlorophyll content after the application of humic acids was observed by Tejda and Gonzales [2003] and Arancon et al. [2006]. The action of foliar application of humic and fulvic acids on chlorophyll increase was also described by Ferrara et al. [2007].

According to the literature data, the effect of extracts from algae on the chlorophyll content in leaves is not identical, and many authors confirm a close relation between the process of formation of the chlorophyll dye and the dose of seaweed extracts. The study where lower doses of seaweed extracts strongly induced a growth in chlorophyll (even by 20%) as compared with the control, and high doses decreased chlorophyll content, were conducted by Jothinayagi and Anbazhagan [2009]. In the authors study no differences were observed in the action of particular doses of the preparations on synthesis of chlorophyll.

## CONCLUSIONS

1. Extracts from brown algae *Ecklonia maxima* and *Saragassum* spp. and humic and fulvic acids improved the germination capacity of maize seeds.

2. The effect of extracts from seaweeds and a mixture of humic and fulvic acids on the weight of shoots and roots depended on the way of their application on plants. The plants sprayed twice with the tested substances had the largest shoots and roots.

3. Plants obtained from seeds soaked in solutions of seaweed extracts were characterized by a higher weight of shoots and roots, as compared with plants obtained from seeds soaked in solutions of humic and fulvic acids.

4. Soaking seeds in solutions of the tested substances and an additional foliar application of extracts from seaweeds and humic and fulvic acids on plants stimulated growth of the maize root system stronger in comparison with the growth of shoots. Humic and fulvic acids had a stronger effect on the root system.

5. Maize plants sprayed twice with the tested substances responded with a strong – 30-68% – growth in shoot and root weight.

6. Further research in field conditions is needed to give practice recommendations concerning the application of seaweed extracts as well as humic and fulvic acids and proving their positive effect on the growth and development of maize.

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## WPLYW EKSTRAKTÓW Z ALG MORSKICH ORAZ KWASÓW HUMINOWYCH I FULWOWYCH NA KIEŁKOWANIE I POCZĄTKOWY WZROST *Zea mays* L.

**Streszczenie.** W latach 2009-2010 w Instytucie Ochrony Roślin przeprowadzono doświadczenia laboratoryjne i szklarniowe, których celem była ocena działania ekstraktów z alg morskich oraz kwasów huminowych i fulwowych na kiełkowanie i początkowy wzrost kukurydzy. W doświadczeniach stosowano ekstrakty z alg morskich *Ecklonia maxima* (Kelpak SL), *Saragassum* spp. (AlgaminoPlant) oraz mieszaninę kwasów huminowych (12%) i fulwowych (6%) (HumiPlant). Działanie preparatów zawierających algi morskie oraz kwasy huminowe i fulwowe na kiełkowanie, zawartość chlorofilu w liściach, masę pędów i korzeni uzależnione było od sposobu ich aplikacji. Ekstrakty z alg morskich bardziej stymulowały kiełkowanie roślin niż kwasy huminowe i fulwowe. Spośród roślin uzyskanych z nasion moczonych w roztworach badanych preparatów największą masą pędów charakteryzowały się rośliny poddane działaniu ekstraktu z *Ecklonia maxima*. Wszystkie badane preparaty wykazały korzystny wpływ na wzrost masy pędów i korzeni roślin uzyskanych z nasion moczonych w roztworach substancji i dodatkowo opryskanych oraz roślin dwukrotnie traktowanych badanymi substancjami. W tych kombinacjach największą masę pędów uzyskano po aplikacji alg *Saragassum* spp., a największą masę korzeni roślin otrzymano w kombinacjach z zastosowaniem substancji huminowych i fulwowych. Spośród badanych wariantów stosowania najkorzystniejszy wpływ na rośliny miała dwukrotna aplikacja nalistna badanych preparatów.

**Słowa kluczowe:** aplikacja nalistna, ekstrakty z alg, kiełkowanie, kwasy huminowe i fulwowe, zawartość chlorofilu

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