POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 28(3): 317–326, Y. 2013

EFFECT OF THE *ECKLONIA MAXIMA* EXTRACT ON SELECTED MICRO- AND MACROELEMENTS IN ABOVE-GROUND BIOMASS OF *FESTULOLIUM BAUNII* (K. RICHT.) A. CAMUS

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Key words: seaweed extract, microelements, macroelements, biomass, *Festulolium baunii*.

Abstract

Studies with *Festulolium braunii* (variety Felopa), cultivation was carried out in the polyurethane rings with a diameter of 36 cm and hight of 40 cm, which were dug to a depth of 30 cm and filled with soil material. In this experiment Kelpak SL (extract from *Ecklonia maxima*) was used as bioregulator. It consists the natural plant hormones such as auxin (11 mg in dm^3) and cytokines (0.03 mg in dm^3). Experimental objects: A1 – control (no extract), A2 – extract. The preparation was applied to all regrowth in the form of spray at a dose of 3 cm^3 $ring^{-1}$ during the grass shooting stage (2 dm^3 preparation diluted in 350 dm^3 of water). The full period of this experiment was in the years 2010–2011. The study traits were: the content of macroelements – phosphorus, potassium, calcium, magnesium (g kg^{-1} DM) and trace elements – manganese, zinc and copper (mg kg^{-1} DM) in the aboveground biomass of *Festulolium baunii*. In the paper ratio of Ca : P and K : (Ca + Mg) was also calculated. The results were analyzed statistically using analysis of variance and the average were compared by according to Tukey's test. As a result of spraying with the extract from seaweed, in *Festulolium baunii* aboveground biomass increased content of phosphorus, potassium, zinc and manganese. The contents of magnesium, calcium and copper did not undergo differentiation under the influence of study factor. In the consequence of differentiation of macroelements content the decrease of the ratio value of calcium to phosphorus and the increase in the ratio of potassium to calcium and magnesium was appered.

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WPŁYW EKSTRAKTU Z *ECKLONIA MAXIMA* NA ZAWARTOŚĆ WYBRANYCH MIKRO- I MAKROELEMENTÓW W BIOMASIE NADZIEMNEJ *FESTULOLIUM BAUNII* (K. RICHT.) A. CAMUS

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Słowa kluczowe: ekstrakt z wodorostów, mikroelementy, makroelementy, biomasa, *Festulolium baunii.*

Abstrakt

Badania z uprawą *Festulolium braunii* (odmiana Felopa) przeprowadzono w pierścieniach poliuretanowych o średnicy 36 cm i wysokości 40 cm, które wkopano na głębokość 30 cm i wypełniono materiałem glebowym. Czynnik doświadczalny stanowił bioregulator o nazwie handlowej Kelpak SL (ekstrakt z *Ecklonia maxima*), w skład którego wchodzą naturalne hormony roślinne, tj. auksyny (11 mg dm^{-3}) i cytokininy (0,03 mg dm^{-3}). Obiekty doświadczalne: A1 – kontrola (bez ekstraktu), A2 – ekstrakt. Preparat aplikowano na wszystkie trzy odrosty w formie oprysku w dawce 3 $cm^3 \cdot$ pierścień$^{-1}$ w fazie strzelania w źdźbło traw (2 dm^3 preparatu rozpuszczonego w 350 dm^3 wody). Okres pełnego użytkowania obiektów doświadczalnych przypadał na lata 2010–2011. Badano następujące cechy: zawartość makroelementów – fosforu, potasu, wapnia, magnezu (g kg^{-1} s.m.) i mikroelementów – manganu, cynku i miedzi (mg kg^{-1} s.m.) w biomasie nadziemnej *Festulolium baunii*. W pracy wyliczono również stosunek Ca : P oraz K : (Ca + Mg). Wyniki opracowano statystycznie, stosując analizę wariancji oraz NIR0,05 według testu Tukey'a. W efekcie stosowania oprysku ekstraktem z wodorostów w biomasie nadziemnej *Festulolium baunii* nastąpił wzrost zawartości fosforu, potasu cynku i manganu. W konsekwencji zróżnicowania zawartości makroelementów nastąpiło zawężenie stosunku wapnia do fosforu i rozszerzenie stosunku potasu do wapnia i magnezu.

Introduction

According to ABOU EL-YAZIED et al. (2012), seaweed is one of the most important marine resources of the world. There are used as human food, animal feed and raw materials for many industries. They are also used as a fertilizer for agricultural and horticultural crops (TEMPLE et al. 1988, BECKETT et al. 1994, OUEDRAOGO et al. 2001, BAI et al. 2007, ZODAPEA et al. 2009, NOUR et al. 2010, ZODAPE et al. 2010, ABOU EL-YAZIED et al. 2012). After applying these extracts in agricultural crops, were found better production results than after the mineral fertilizers (AITKEN and SENN 1965, THIRUMARAN et al. 2009, NOUR et al. 2010). Due to the presence of minerals and hormonal substances (MOLLER and SMITH 1998, 1999), they cause an increase of plant resistance to stress and disease conditions (VERKLEIJ 1992). The chemistry of

seaweed is complex, it has a very high content of organic carbon (particularly carbohydrates such as alginic acid, laminaren and mannitol), seaweed is also high in polysaccharides but yet very low in N, P, K, seaweed is well known for its trace mineral content and the presence of a range of biologically active, growth promoting substances. Seaweed concentrates are known to cause many beneficial effects on plants as they contain growth promoting hormones (IAA and IBA, cytokinins), trace elements (Fe, Cu, Zn, Co, Mo, Mn, and Ni), vitamins and amino acids (KHAN et al. 2009, ZODAPE et al. 2010, ABOU EL-YAZIED et al. 2012). Today, these preparations are seen as a natural organic fertilizer of new generation (AITKEN and SENN 1965, SINGH and CHANDELA 2005, SRIDHAR and RENGASAMY 2010, ZODAPE et al. 2010, ABOU EL-YAZIED et al. 2012). The beneficial effect of biostimulators fitohormons on based primarily reflected on yield increase (TEMPLE and BOMKE 1989, LIU et al. 1991, VERKLEIJ 1992, MOSTAFA and ZHEEKH 1999, ZODAPE 2001, MATYSIAK and ADAMCZEWSKI 2006, MATYSIAK et al. 2012). The application of these products also affected the content of micro-and macronutrients in plant material (RATHORE et al. 2009, ZODAPE et al. 2009, ABOU EL-YAZIED et al. 2012). In literature already described the effect of extracts on cereals and vegetables, but there is no response studies on the application of such preparations *Festulolium baunii* (K. Richt.) A. Camus.

Study was undertaken to determine the effect of the extract from *Ecklonia maxima* on content of selected micro- and macroelements in above-ground biomass of *Festulolium baunii*. The experiment was to demonstrate that the annually use of extract over the next two years of *Festulolium baunii* growing, influenced the content of P, K, Mg, Ca, Mn, Zn, and Cu in the tested plant material.

Materials and Methods

Studies of with growing of *Festulolium braunii* cv. 'Felopa', was carried out in the polyurethane rings, with 4 replications at the experimental object of Grassland and Development of the Department of Landscape Architecture. Rings with a diameter of 36 cm and height of 40 cm were dug to a depth of 30 cm and filled with soil material belonging to the soil of hortisole type, formed from weakly loamy sand. On the basis of chemical analysis performed at the Regional Chemical Station in Wesoła it was stated, that the soil in the rings was characterized by a neutral reaction (pH in 1 mol KCl dm^{-3} = 7.2), high abundance in humus (3.78%), available phosphorus (P – 395 mg kg^{-1}) and magnesium (Mg – 84 mg kg^{-1}) and the average abundance of nitrogen (N total – 1.8 g kg^{-1}) and soluble potassium (K – 157 mg kg^{-1}). For each of the rings

(3 April 2010), six seeds of tested grass species were sown. After seeds germination when seedlings reached the 2–3 leaf stage, negative selection was made by removing the two weakest plants, and than it was introduced an experimental factor as a growth regulator – Kelpak SL. It is a preparation, consisting from natural plant hormones such as auxin (11 mg in dm^3) and cytokinins (0.03 mg in dm^3). It is prepared from brown algae *Ecklonia maxima* (TEMPLE et al. 1988). Experimental objects: A1 – control (noextract), A2 – extract. The preparation was applied to all regrowth in the form of spray at a dose of 3 cm3 $ring^{-1}$ during the grass shooting stage (2 dm^3 preparation was diluted in 350 dm^3 of water). In addition, mineral fertilizers were used in the annual dose: N – 0.6 g $ring^{-1}$ and K – 0.74 g $ring^{-1}$. The full period of three cut using of experimental objects was in the years: 2010–2011.

The content of micro- and macroelements in the biomass has determined for all the cuts over three years of this crop. The following methods for analizing was used: P – flow spectroscopy, K – emissions by flame spectroscopy, Ca and Mg – atomic absorption spectroscopy. Furthermore, based on macroelements the content of the following ratios were calculated Ca : P and K: (Ca + Mg). Chemical analyzes on the contents of Mn, Zn and Cu by atomic absorption spectrometry.

The obtained results were evaluated statistically by using analysis of variance for multivariante experiments. Differentiation of medium was verified by Tukey's test at significance level $p \leq 0.05$.

Weather conditions of research area were typical for IX – eastern district of agro-climatic of Poland (RADOMSKI 1977). Average annual air temperature ranged from 6.7–6.9 °C, and in summer the average daily temperature is 15°C. Annual precipitation are at the level 550–650 mm, while they are not frequent, but heavy. The vegetation period usually begins in the first decade of April and ends in the third one of October, and so takes from 200 to 220 days. Meteorological data from the research years were obtained from the Hydrological and Meteorological Station in Siedlce. However, in order to determine the temporal and spatial variability of meteorological elements and their effects on vegetation the hydrothermal index of Sielianinov (BAC et al. 1993) was calculated. This values for individual months and years of research are presented in Table 1.

The data in Table 1 indicate, that the most favorable distribution and the amount of rainfall, with optimum air temperatures within the vegetation period for plants growing characterized 2011. In that year there were no months with strong drought inverse to the year 2010.

Table 1

Value of hydrothermal index of Sielianinov (K) in individual months of vegetation

Year	Month						
	IV	V	VI	VII	VIII	IX	X
2010	0.40	2.21	1.19	1.18	1.79	2.81	0.53
2011	1.10	0.89	0.72	2.19	0.84	0.78	0.94

$K < 0.5$ – serve drougth; 0.51–0.69 – drougth; 0.70–0.99 – poor drougth; $K > 1$ – no drought

Results and discussion

The spray using the extract from *Ecklonia maxima* in the cultivation of *Festulolium baunii* resulted in a significant increase in phosphorus content over 13,5% and over 16,5% of potassium (Table 2). The statistical analysis also showed that the content of these elements were also dependent on the year. The smallest amount of phosphorus (3.73 g kg^{-1} D.M. – mean for cut), independently of the research factor was occurred in the second year of cultivation, but the greatest was in the first year (4.23 g kg^{-1} D.M. – mean for cut). However, the potassium content increased with aging plants. It is worth noting that the use of extract in each year of the experiment did not significantly affect the content of magnesium and calcium in the tested plant material. This is confirmed in a study conducted by ABOU EL-YAZIED et al. (2012), but does not correspond to the results obtained by ZODAPE et al. (2009), which reported a significant increase in the content of these macronutrients in cereal grains.

Numerous studies (FEATONBY-SMITH, STADEN 1983, VERKLEIJ 1992, GALBIATTIA et al. 2007) have shown that the beneficial effects with the use of seaweed extracts as natural regulators increased yield, improved plant vigor, and the ability to resisting unprofitable environmental conditions. The using of the extract as an organic biostimulator, was quickly accepted by practice in horticulture because of the beneficial production effects (VERKLEIJ 1992, CROUCH, STADEN 1993). According to SANDERSON and JAMESON (1986) or STIRK and VAN STADEN (1997) the main components of extracts affecting on the plants are cytokinins and auxins, which have been identified in most seaweed concentrates.

According to WIERZBOWSKA, BOWSZYS (2008), these hormones induce many processes connected with histological and cytological aspects of plants and influence on the content of some macronutrients. From the research of ABOU EL-YAZIED et al. (2012) on the effects of seaweed extracts on the beans quality resulted that the application during two growing seasons, resulted in an increase in the content of phosphorus and potassium in the leaves in compare

to control. The same trend also concerned magnesium content. Similar results are presented by PISE and SABALE (2010). The increase in the content of phosphorus and potassium, in plant material after extract spray application were also found by SHEHATA et al. (2011). Also NOUR et al. (2010) studying the effect of extracts spray from seaweed on the chemical composition of tomato showed that the most of K and P occurred in vegetables grown on the objects with this factor. Studies on soybean (RATHORE et al. 2009), relating to the response of this plant to the different concentrations of the extracts from seaweed, also showed a significant increase in P and K content after extract application regardless of the concentration. The ZODAPE et al. (2009), using 1% spray with extract on wheat stated in the grain more than 15% increase of K content 18% P, 45% Ca and 28% Mg. The increase in the content of macronutrients in plants after application of extracts was also reported by BECKETT et al. (1994) and ZAHID (1999).

Table 2

Effect of the extract from *Ecklonia maxima* on the content of selected macroelements [g kg^{-1} D.M.] in biomass of *Festulolium braunii* in each study years and cuts

Years	Cut 1			Cut 2			Cut 3			Extract		Mean
	extract			extract			extract					
	A1	A2	mean	A1	A2	mean	A1	A2	mean	A1 control	A2 factor	
P												
2010	4.11^{Aa}	4.01^{Ba}	4.06^{B}	2.92^{Bb}	3.93^{Ba}	3.43^{B}	3.23^{Aab}	4.11^{Aa}	3.67^{B}	3.44^{Bb}	4.03^{Ba}	3.74^{B}
2011	4.30^{Aa}	4.63^{Aa}	4.47^{A}	3.81^{Aa}	4.41^{Aa}	4.11^{A}	3.92^{Aa}	4.20^{Aa}	4.06^{A}	4.02^{Ab}	4.42^{Aa}	4.22^{A}
Mean	$4.20a$	4.32^{a}	4.26^{a}	3.41^{b}	4.22^{a}	3.77^{b}	3.63^{b}	4.20^{a}	3.87^{ab}	3.73^{b}	4.23^{a}	–
K												
2010	33.5^{Aa}	35.8^{Aa}	34.7^{A}	$32{,}9^{Ab}$	38.0^{Aa}	35.5A	32.9^{Ab}	38.7^{Aa}	35.6^{A}	33.1^{Ab}	37.5^{Aa}	35.3^{A}
2011	32.4^{Ab}	39.1^{Aa}	35.8^{A}	33.0^{Ab}	40.6^{Aa}	36.8^{A}	34.5^{Ab}	40.0^{Aa}	37.3^{A}	33.3^{Ab}	39.9^{Aa}	36.6^{A}
Mean	33.0^{a}	37.5^{a}	35.3^{a}	33.0^{b}	39.3^{a}	36.2^{a}	33.7^{b}	39.4^{a}	36.5^{a}	33.2^{b}	38.7^{a}	–
Mg												
2010	5.81^{Aa}	5.10^{Aa}	5.46^{A}	4.82^{Bb}	5.23^{Aa}	5.03^{A}	5.61^{Aa}	5.30^{Aa}	5.46^{A}	5.41^{Aa}	5.21^{Aa}	5.31^{A}
2011	5.32^{Aa}	5.61^{Aa}	5.47^{A}	5.20^{Aa}	5.31^{Aa}	5.26^{A}	5.41^{Aa}	5.34^{Aa}	5.38^{A}	5.31^{Aa}	5.42^{Aa}	5.41^{A}
Mean	5.57^{a}	5.36^{a}	5.47^{a}	5.01^{a}	5.27^{a}	5.14^{a}	5.51^{a}	5.32^{a}	5.42^{a}	5.41^{a}	5.31^{a}	5.31^{A}
Ca												
2010	7.20^{Aa}	7.10^{Aa}	7.15^{Aa}	7.23^{Aa}	6.65^{Aa}	6.94^{Aa}	6.90^{Aa}	7.01^{Aa}	6.96^{Aa}	7.11^{Aa}	6.92^{Aa}	7.02^{Aa}
2011	7.01^{Aa}	7.01^{Aa}	7.01^{Aa}	7.44^{Aa}	7.00^{Aa}	7.22^{Aa}	7.21^{Aa}	7.03^{Aa}	7.12^{Aa}	7.22^{Aa}	7.01^{Aa}	7.12^{Aa}
Mean	7.11^{a}	7.06^{a}	7.09^{a}	7.34^{a}	6.83^{a}	7.08^{a}	7.06^{a}	7.02^{a}	7.04^{a}	7.21^{a}	7.01^{a}	–

Mean values marked with the same small letters do not differ significantly, and mean values marked with the same capital letters do not differ significantly

In the literature relating to the nutritional value of the feed material emphasizes the importance of quantitative relationships of individual minerals as a parameter describing the nutritional value of plants (STANIAK 2004, JANKOWSKA-HUFLEJT, WRÓBEL 2008, NOWAK et al. 2008). According to STANIAK (2004), it is important to determine the ratio of Ca:P and K: (Ca+Mg). In the analyzed plant material, regardless of the study year, the using of an extract significantly reduced the ratio of calcium to phosphorus (Table 3), from 1.94 to 1.66 (mean for cut). The experiment biomass has a very high content of K in relation to animal nutrition standards (JANKOWSKA-HUFLEJT, WRÓBEL 2008). It influenced to a significant decrease in the ratio K: (Ca+Mg), which in plant material collected from control crops amounted 2.66. It should be noted, however, that spraying the *Festulolium braunii* with extract caused a statistically significant, over 31% increase in its value. In the subsequent study years occurred an increase of K content (Table 2), which also resulted in the increase of K: (Ca+Mg) ratio to a value greater than 3 (Table 3).

Table 3

Macronutrient ratios in biomass of *Festulolium braunii* depending on the extract of *Ecklonia maxima* and the growing years and cuts

Years	Cut 1			Cut 2			Cut 3			Extract		Mean
	extract			extract			extract					
	A1	A2	mean	A1	A2	mean	A1	A2	mean	A1 control	A2 factor	
K : (Ca+ Mg)												
2010	2.57^{Aa}	2.93^{Aa}	2.75^{A}	2.73^{Ab}	3.20^{Aa}	2.97^{A}	2.63^{Ab}	3.14^{Aa}	2.89^{A}	2.65^{Ab}	3.10^{Aa}	2.87^{A}
2011	2.63^{Ab}	3.10^{Aa}	2.87^{A}	2.61^{Ab}	3.30^{Aa}	2.96^{A}	2.73^{Ab}	3.23^{Aa}	2.98^{A}	2.66^{Ab}	3.22^{Aa}	2.94^{A}
Mean	2.60^{b}	3.02^{a}	2.81^{a}	2.67^{b}	3.25^{a}	2.97^{a}	2.68^{b}	3.19^{a}	2.94^{a}	2.66^{b}	3.16^{a}	–
Ca : P												
2010	1.75^{Aa}	1.77^{Aa}	1.76^{A}	2.48^{Aa}	1.69^{Ab}	2.09^{A}	2.14^{Aa}	1.71^{Aa}	1.93^{A}	2.08^{Aa}	1.73^{Ab}	1.91^{A}
2011	1.63^{Aa}	1.51^{Aa}	1.57^{A}	1.95^{Aa}	1.58^{Aa}	1.77^{A}	1.84^{Aa}	1.67^{A}	1.76^{A}	1.80^{Aa}	1.59^{Aa}	1.70^{A}
Mean	1.69^{b}	1.64^{a}	1.67^{a}	2.22^{a}	1.64^{a}	1.93^{a}	1.99^{a}	1.69^{a}	1.84^{a}	1.94^{a}	1.66^{b}	–

Mean values marked with the same small letters do not differ significantly, and mean values marked with the same capital letters do not differ significantly

Spraying of *Festulolium braunii* plants with extract from seaweed led to a significant increase (Table 4) the content of Mn and Zn in aboveground biomass. The manganese content increased from 127 on control object to 149 mg kg^{-1} DM – objects with preparation (mean for cut). This represented more than 17% increase in value. However, in the case of zinc has been noted the increase more than 9% compared to control object.

The statistical evaluation regardless of study years hadn't significant medium differentiation after application of factor in relation to the content of copper. In addition, analyzing the micronutrients content should be noted, that in the biomass of *Festulolium braunii* significant differentiated copper content only. The largest amount of this element was observed in the material collected in the first study year. The increase in the content of some micro elements was also stated in the study of ZODAPE et al. (2009).

Table 4

Effect of the extract from *Ecklonia maxima* on the content of selected microelements [mg kg^{-1} D.M.] in biomass of *Festulolium braunii* in each study years and cuts

Years	Cut 1			Cut 2			Cut 3			Extract		Mean
	extract		mean	extract		mean	extract		mean			
	A1	A2		A1	A2		A1	A2		A1 control	A2 factor	
Mn												
2010	130^{Aa}	150^{Aa}	140^{A}	130^{Ab}	151^{Aa}	141^{A}	127^{Ab}	149^{Aa}	138^{A}	129^{Ab}	150^{Aa}	140^{A}
2011	137^{Aa}	148^{Aa}	143^{A}	117^{Ab}	148^{Aa}	133^{A}	121^{Ab}	148^{Aa}	135^{A}	125^{Ab}	148^{Aa}	137^{A}
Mean	134^{a}	149^{a}	142^{a}	124^{b}	150^{a}	137^{a}	124^{b}	149^{a}	137^{a}	127^{b}	149^{a}	–
Zn												
2010	44.7^{Ab}	51.0^{Aa}	47.9^{Ab}	47.0^{Aa}	50.5^{Aa}	48.8^{Ab}	46.0^{Ab}	50.3^{Aa}	48.2^{Ab}	45.9^{Aa}	50.6^{Aa}	48.3^{Ab}
2011	45.8^{Aa}	50.1^{Aa}	47.9^{Ab}	47.1^{Aa}	49.4^{Aa}	48.3^{Ab}	46.0^{Aa}	49.9^{Aa}	48.0^{Ab}	46.3^{Ab}	49.8^{Aa}	48.1^{Ab}
Mean	45.3^{b}	50.6^{a}	47.9^{a}	47.1^{a}	50.0^{a}	48.6^{a}	46.0^{b}	50.1^{a}	48.1^{a}	46.1^{b}	50.2^{a}	–
Cu												
2010	9.50^{Aa}	8.88^{Aa}	9.19^{A}	9.76^{Aa}	9.11^{Aa}	9.44^{A}	9.60^{Aa}	9.01^{Aa}	9.31^{A}	9.62^{Aa}	9.00^{Aa}	9.31^{A}
2011	9.10^{Aa}	9.49^{Aa}	9.30^{A}	9.32^{Aa}	9.24^{Aa}	9.28^{A}	9.06^{Aa}	9.41^{Aa}	9.24^{A}	9.16^{Aa}	9.38^{Aa}	9.27^{A}
Mean	9.30^{a}	9.19^{a}	9.25^{a}	9.54^{a}	9.18^{a}	9.36^{a}	9.33^{a}	9.20^{a}	9.28^{a}	9.39^{a}	9.19^{a}	–

Mean values marked with the same small letters do not differ significantly, and mean values marked with the same capital letters do not differ significantly

According to the authors, the application of the extract from *K. alverezii* in cereals, regardless of the preparation concentration, resulted in an increase of zinc content (4.9%) and manganese (9.42%) in wheat grain. Only the copper content did not undergo differentiation under the influence of the extract.

Conclusions

1. The application of the extract from *Ecklonia maxima* in the cultivation of *Festulolium braunii* resulted in a statistically significant increase in the content of P and K in the above-ground parts of this plant.

2. The content of Mg and Ca in the biomass of *Festulolium braunii* did not undergo significant differentiation both under the influence of an extract of seaweed as well as research years.

3. Both the K: (Ca+Mg) ratio Ca:P and levels are changed significantly as a result of the extract application. The ratio of K to Ca and Mg increased by 31% and Ca to P was reduced by 17%.

4. Spraying with seaweed extract resulted in an increase in the content of Mn and Zn in the dry matter of *Festulolium braunii*. Copper did not undergo to significant variation under the preparation influence.

5. The study did not show clearly in which conditions there was the most favorable effect of the extract of *Ecklonia maxima* for the content of micro- and macronutrients in *Festulolium braunii* biomass.

Translated by Kazimierz Jankowski

Accepted for print 5.09.2013

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