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EFFECT OF GROWTH REGULATOR KELPAK SL ON THE FORMATION OF ABOVEGROUND BIOMASS OF *Festulolium braunii* (K. RICHT.) A. CAMUS

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Abstract

A study on the cultivation of *Festulolium braunii* cv. 'Felopa' was carried out using polyurethane rings with a diameter of 36 cm and a height of 40 cm, which were sunk into the ground to a depth of 30 cm and filled with soil material. In this experiment, Kelpak SL was used as a bioregulator. It consists of natural plant hormones such as auxins (11 mg in dm^3) and cytokinins (0.03 mg in dm^3). The experimental factors were as follows: A1-control; A2 – 20% solution of the growth regulator; A3 – 40% solution; and A4 – 60% solution. The preparation was applied to all three regrowths in the form of spray, at a rate of 3 cm^3 $ring^{-1}$, at the stem elongation stage. The full period of this experiment was in the years 2010–2011. During this time, detailed investigations were carried out on aboveground biomass yield (g DM $ring^{-1}$), number of shoots (pcs $ring^{-1}$), leaf blade length (cm), width of the leaf blade base (mm), leaf greenness index (SPAD). The study showed a significant effect of the growth regulator on the formation of *Festulolium braunii* biomass. However, its highest effectiveness was observed when the 60% solution was applied.

Key words: *Festulolium braunii*, phytohormons application, shoots, yield, SPAD

INTRODUCTION

The research (Zodape, 2001; Masny et al. 2004) shows that the application of plant hormones in cultivation helps in the process of plant adaptation to stress conditions. It has also been demonstrated that plants treated with extracts containing auxin and cytokinin are more resistant to drought, lack of nutrients in the soil, and salinity. Moreover, they effectively reduce the stress associated with plant seeding. The beneficial effect of phytohormone-based biostimulators is primarily reflected in an increase in yield (Temple and Bomke, 1989; Verkleij, 1992; Zodape, 2001; Russell, 2002; Masny et al. 2004; Matysiak, 2005; Matysiak and Adamczewski, 2006; Matysiak et al. 2012). Preparations of this type have been made on an industrial scale on the basis of extracts of green algae: *Enteromorpha intestine*, *Cladophora dalmatica*, *Ulva lactuca*, and kelp – *Corralina mediterranea*, as well as brown algae – *Ecklonia maxima* (Bai et al. 2007). The scientific reports highlight the possibility of using in agricultural crops a commercially available preparation, Kelpak, which the research has shown to have a positive effect on the yield of crops. It has also been underlined that various species and even cultivars respond differently to the application of hormonal regulators. The largest increase in yield after treatment with Kelpak was obtained for plants of the *Monocotyledones* class, especially cereals. But species such as white mustard and pea are less responsive to the preparation (Matysiak and Adamczewski, 2006; Matysiak et al. 2012). This fact was the basis for undertaking a study on the possibility of using hormonal regulators in grass crops valuable as animal feed. The analysis of the literature (Zwierzykowski et al. 1993; Borowiecki, 1997; Domanski and Jokś, 1999; Henning et al. 2002; Staniak, 2005; Gutman and Adamovich, 2008; Franks-Lindberg and Olsson, 2008; strem and Larsen, 2008; Sosnowski and Jankowski, 2010; Sosnowski, 2011) indicates the growing importance of *Festulolium braunii* in this respect. It can be noted, however, that there is a lack of studies on the cultivation of this species supplied with preparations based on plant hormones.

The aim of this study was to determine the effect of Kelpak SL on the formation of aboveground biomass and SPAD values of leaf blades of *Festulolium braunii* 'Felopa'.

MATERIALS AND METHODS

The study on the cultivation of *Festulolium braunii* 'Felopa' was carried out in polyurethane rings, with 4 replications per experimental treatment, at the Department of Grassland and Development of Landscape Architecture. Rings with a diameter of 36 cm and a height of 40 cm were sunk into the ground 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 found that the soil in the rings was characterized by neutral pH (pH in 1N KCl = 7.2), a high content of humus (3.78%) and available phosphorus ($P_2 0_5$ – 900 mg × kg^{-1}) and magnesium (Mg – 84 mg × kg^{-1}), as well as a medium content of nitrogen (N – 1.8 g × kg^{-1}) and bioavailable potassium ($K_2 0$ – 190 mg × kg^{-1}). In each ring, six seeds of the tested grass species were sown (3 April 2010). After seed germination, when seedlings reached the 2–3 leaf stage, negative selection was made by removing the two weakest plants and then the growth regulator Kelpak SL was introduced as an experimental factor. It is a preparation consisting of natural plant hormones such as auxins (11 mg in dm^3) and cytokinins (0.03 mg in dm^3). It is prepared from brown algae *Ecklonia maxima* (M a t y s i a k et al. 2012).

The experimental factors were as follows: A1--control; A2 – 20% solution of the growth regulator; A3 – 40% solution; and A4 – 60% solution. The preparation was applied to all three regrowths in the form of spray, at a rate of $3cm^3$ $ring^{-1}$, at the stem elongation stage.

In addition, mineral fertilizers were used at the following annual rate: N – 0.6 g × $ring^{-1}$; P_2O_5 – 0.25 g $ring^{-1}$; and K_2O – 0.9 g × $ring^{-1}$.

The full experimental period was in the years 2010–2011, with three cuts of grass in each year. During this time, detailed investigations of the following traits were performed:

– aboveground biomass yield (g DM $ring^{-1}$);
– number of shoots (pcs $ring^{-1}$);
– leaf blade length (cm);
– width of the leaf blade base (mm);
– leaf greenness index (SPAD).

Measurements of leaf length and its width at the base were made on 10 randomly selected leaves from each experimental treatment at the boot stage. On the same blades, the SPAD index was also measured in 10 replicates, using a SPAD-502 meter (Spectrum Technologies).

The results were evaluated statistically by analysis of variance. Differences between means were determined by Tukey's test at the significance level $p \leq 0.05$.

Weather conditions of the research area were typical for the eastern district (IX) of agro-climatic regions of Poland (R a d o m s k i , 1977). Average annual air temperature ranged 6.7–6.9°C, whereas in summer the average daily temperature was 15°C. Annual precipitation is at a level of 550–650 mm; rainfall is not frequent, but heavy. The growing seasons usually begins in the first 10-day period of April and ends in the third 10-day period of October, so it lasts from 200 to 220 days.

Meteorological data from the study 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, Selyaninov's hydrothermal coefficient was calculated (B a c et al. 1993). The values for individual months and years of the study are presented in Table 1.

The data presented in Table 1 show that the year of 2011 was characterized by the most favourable distribution and amount of rainfall, with optimum air temperatures for plant growth during the growing period. In that year, there were no months with strong drought contrary to 2010.

Table 1
Values of Selyaninov's hydrothermal coefficient (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 – severe drought; 0.51 – 0.69 – drought; 0.70 – 0.99 – weak drought; K > 1 – no drought

RESULTS

An important factor for fertilization of crops is the amount and quality of yield. The analysis of the results showed that, regardless of year, significantly the highest yield was obtained for the crops grown in the ring where the spray with the 60% solution biopreparation – A4 was applied (Table 2). The average yield for this treatment was 91.69 g dry matter per ring and it was about 16% higher than in the control treatment – A1. The use of lower concentrations did not result in yield increases compared to the control treatments A2 and A3. It should also be noted that years did not differentiate significantly the investigated traits.

Table 2
Aboveground biomass yield (g DM ring^{-1}) of *Festulolium braunii* depending on the applied growth regulator and study year (total for cuts)

Year	Bioregulator				
	A1	A2	A3	A4	Mean
2010	79.96 Ac	85.03 Ab	79.43 Ac	93.00 Aa	84.36 A
2011	77.80 Ab	70.73 Bb	78.80 Ab	90.38 Aa	79.43 A
Mean	78.75 b	77.88 b	79.12 b	91.69 a	

Means in lines marked with the same small letters do not differ significantly.
Means in columns marked with the same capital letters do not differ significantly.

A1 – control (no bioregulator); A2 – 20% solution of growth regulator; A3 – 40%; A4 – 60%

The number of shoots formed as well as leaf blade length and its width at the base had a large effect on the structure of aboveground biomass, because these features directly affect the leaf surface. As shown by the data in Table 3, regardless of year, significantly the highest number of shoots (185.46 pc ring^{-1}) was found in the treatments with the highest concentration – A4. Noteworthy is the fact that, as was in the case of yield, the lower concentration of this factor did not influence significantly the number of shoots. During the experiment, the leaf blade length, at a level of 28.8 cm (Table 4), was the highest for crops treated with the 40 and 60% solution of Kelpak. The study also showed a lack of variation in leaf blade width of *Festulolium braunii* (Table 5), both for the main factor and study years. Its value was on average 7.17 mm.

Table 3
The number of shoots (pcs ring^{-1}) of *Festulolium braunii* depending on the applied growth regulator and study year (mean for cuts)

Year	Bioregulator				
	A1	A2	A3	A4	Mean
2010	170.80 Ab	175.40 Ab	176.26 Ab	184.86 Aa	176.83 A
2011	167.26 Ab	170.00 Ab	163.40 Bb	186.06 Aa	171.68 A
Mean	169.03 b	172.70 b	169.83 b	185.46 a	

Means in lines marked with the same small letters do not differ significantly.
Means in columns marked with the same capital letters do not differ significantly.

A1 – control (no bioregulator); A2 – 20% solution of growth regulator; A3 – 40%; A4 – 60%

Table 4
Length of leaf blade (cm) of *Festulolium braunii* depending on the applied growth regulator and study year (mean for cuts)

Year	Bioregulator				
	A1	A2	A3	A4	Mean
2010	23.86 Ab	22.44 Ab	28.18 Aa	30.16 Aa	26.16 A
2011	21.08 Ab	24.00 Ab	29.94 Aa	26.86 Bab	25.47 A
Mean	22.47 b	23.22 b	29.06 a	28.51 a	

Means in lines marked with the same small letters do not differ significantly.
Means in columns marked with the same capital letters do not differ significantly.

A1 – control (no bioregulator); A2 – 20% solution of growth regulator; A3 – 40%; A4– 60%

Table 5
Width of the leaf blade base (mm) of *Festulolium braunii* depending on the applied growth regulator and study year (mean for cuts)

Study years	Bioregulator				
	A1	A2	A3	A4	Mean
2010	7.68 Aa	7.00 Aa	6.18 Bb	7.42 Aa	7.07 A
2011	6.94 Bb	7.48 Aa	7.78 Aa	6.85 Bb	7.26 A
Mean	7.31a	7.24 a	6.98 a	7.14 a	

Means in lines marked with the same small letters do not differ significantly.
Means in columns marked with the same capital letters do not differ significantly.

A1 – control (no bioregulator); A2 – 20% solution of growth regulator; A3 – 40%; A4 – 60%

During the whole research period, the applied biostimulator differentiated significantly the SPAD value in leaf blades of the tested grass species. Measurements of the leaf greenness index showed that plants sprayed with the highest concentrations of the growth regulator (A4) were characterized by a significantly larger amount of chlorophyll pigments (Table 6). The average SPAD value for these treatments is about 12% higher than for the control – A1. The use of 40% concentration did not differentiate significantly the characters in question in relation to the control, and spraying plants with the 20% solution of Kelpak, caused a decrease in the SPAD value from 41.69 (control – A1) to 34.38 (the treatment with the lowest level of the factor – A2).

It should be noted that the level of chlorophyll in the leaves of *Festulolium braunii* changed over the study years and was the highest in 2011. The fact that there was no severe drought during this period (Table 1) favoured the accumulation of chlorophyll pigment in plants, and the average SPAD value was about 42.

Table 6
The leaf greenness index (SPAD) of *Festulolium braunii* depending on the applied growth regulator and study year (mean for cuts)

Year	Bioregulator				
	A1	A2	A3	A4	Mean
2010	38.70 Bb	31.50 Bc	39.82 Aab	45.82 Aa	38.96 B
2011	44.68 Aa	37.25 Ab	39.60 Aab	47.60 Aa	42.28 A
Mean	41.69 b	34.38 c	39.71b	46.71a	

Means in lines marked with the same small letters do not differ significantly.
Means in columns marked with the same capital letters do not differ significantly.

A1 – control (no bioregulator); A2 – 20% solution of growth regulator; A3 – 40%; A4 – 60%

DISCUSSION

The action of preparations based on plant hormones is strongly dependent on the concentration, what was confirmed in our study. Additionally, it depends on application methods, species and variety of the plant (Sultan et al. 2005). The bioregulator Kelpak does not destroy crops (Temple and Bomke, 1989; Verkleij, 1992; Zodape, 2001; Russell, 2002; Pietryga and Matysiak, 2003; Matysiak, 2005; Matysiak and Adamczewski, 2006), but according to the literature extracts of marine algae can both stimulate and inhibit plant growth. In greenhouse experiments, De Villiers et al. (1983) did not find a significant effect on growth and development of crops studied, while the results obtained in the present study clearly showed the beneficial effects of algae extracts on the formation of aboveground biomass of *Festulolium braunii*. A similar trend was described in the work of Matysiak (2005). According to Matysiak and Adamczewski (2006), corn was the plant that was affected to the greatest extent by the applied bioregulator. The present study shows that Kelpak increased yield of the plant over 21% compared to the control treatment. Some studies also reveal significant differences in yield of cereals, although spring cereals are more strongly responsive to the use of hormones than winter cereals. As a result of foliar treatment of the crop with algae extracts containing phytohormones, in their study Bai et al. (2007) obtained about 35% longer shoots and about 22% longer roots, compared to the control treatment. Similar results are presented by Thevanathan et al. (2005) and De Villiers et al. (1983).

The literature about the impact of hormone-based bioregulators on plants shows their differing effects on the level of chlorophyll pigments. Kelpak applied in the cultivation of *Festulolium* increased the leaf greenness index. The increase in SPAD values, after the application of algal extracts, was also obtained by Blunden et al. (1996), while adverse effects on this trait were observed by Venkataraman Kumar and Mohan (1997).

The scientific studies that prove the beneficial effects of Kelpak on crops indicate a greater importance of the date of biopreparation application than its doses (Matysiak et al. 2012). In addition, some varieties of the same species are characterized by greater susceptibility to hormonal preparations (Matysiak and Adamczewski, 2006).

CONCLUSIONS

1. The use of the biostimulator based on phytohormones caused a significant increase in dry matter yield, number of shoots, and leaf blade length of *Festulolium braunii*. However, the highest values of these characters were observed in plants sprayed with Kelpak solutions at 60% concentration.
2. Measurements of the leaf greenness index showed that crops grown on the plots sprayed with the 60% solution of the growth regulator were characterized by significantly higher SPAD values. The use of the 20% concentration of Kelpak caused a more than 17% decrease in this parameter compared to the control treatment.
3. The study showed a positive effect of the hormonal growth regulator Kelpak on the formation of *Festulolium braunii* biomass.

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Authors' contributions

The following declarations about authors' contributions to the research have been made: concept of the study: JS, KJ, field work: JS, KJ, BW-K, writing – JS, KJ.

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Wpływ bioregulatora Kelpak SL na kształtowanie się biomasy nadziemnej *Festulolium braunii* (K. Richt.) A. Camus

Streszczenie

Badania dotyczące uprawy *Festulolium braunii* '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, w skład którego wchodzą naturalne hormony roślinne tj. auksyny (11 mg × l^{-1}) i cytokininy (0,03 mg × l^{-1}). Obiekty doświadczalne: A1 – kontrola oraz z roztworem bioregulatora A2 – 20%, A3 – 40% i A4 – 60%. Preparat aplikowano na trzy odrosty roślin w formie oprysku, w dawce 1cm^3· pierścień$^{-1}$, w fazie strzelania w źdźbło. Okres pełnego użytkowania obiektów doświadczalnych przypadał na lata 2010–2011. W tym czasie szczegółowymi badaniami objęto plon biomasy nadziemnej (g s.m·pierścień$^{-1}$), liczbę pędów (szt × pierścień$^{-1}$), długość blaszki liściowej (cm), szerokość podstawy blaszki liściowej (mm), indeks zieloności liścia (SPAD). Przeprowadzone badania wykazały istotny wpływ bioregulatora na kształtowanie się biomasy *Festulolium braunii*. Największą jego skuteczność odnotowano stosując opryski 60% roztworami.