The effect of seaweed *Ecklonia maxima* extract and mineral nitrogen on fodder grass chemical composition

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Received: 27 May 2015 / Accepted: 14 September 2015 / Published online: 26 September 2015
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**Abstract** The objective of this study was to determine the effect of the biostimulant Kelpak and different nitrogen rates on cellulose, hemicellulose and lignin contents as well as non-structural carbohydrates in orchard grass and Braun’s festulolium. The experiment was a split-plot arrangement with three replicates. It was set up at the experimental facility of the University of Natural Sciences and Humanities, Siedlce, in late April 2009. The following factors were examined: biostimulant with the trade name Kelpak SL applied at 2 dm³ ha⁻¹ and a control—no biostimulant; nitrogen application rates 50 and 150 kg ha⁻¹ and a control (0 kg ha⁻¹); pure stands of grass species grown in monoculture—orchard grass (*Dactylis glomerata*), cv. Amila,—Braun’s festulolium (*Festulolium braunii*), cv. Felopa. Kelpak significantly increased non-structural carbohydrates, and increasing nitrogen rates reduced the concentration of these components in plants. Increasing nitrogen rates significantly decreased cellulose, hemicellulose, lignin and non-structural carbohydrate contents. Compared with orchard grass, Braun’s festulolium proved to be of a higher nutritional value due to lower cellulose, hemicellulose, lignin and non-structural carbohydrate contents. The aforementioned contents in the grasses differed significantly depending on the cut. Most cellulose and non-structural carbohydrates were determined in second-cut grass whereas most hemicellulose and lignin in second-cut grass.

**Keywords** Growth regulators · Braun’s festulolium · Orchard grass · Carbohydrates · Lignin · Fertilisation

**Introduction**

Eco-friendly trends in plant cultivation and concern for the soil environment on the one hand and production of high, good-quality yields on the other make it necessary to implement new crop plant cultivation technologies (Jankowski et al. 2014). Plant growth and development regulators, even when applied at small amounts to modify plant physiological processes (Matysiak and Adamczewski 2006), have been recently more and more frequently applied in agriculture worldwide. Many scientific reports (Masny et al. 2004; Matysiak et al. 2011) have demonstrated that an application of biostimulants positively affects the overall status of the plant, increases resistance to diseases and pests and improves yield quality (Russell 2002). Sea algae extracts are the most popular growth regulators. They contain high levels of plant hormones, in particular cytokinins, polysaccharides, amino acids and macro- and micro-elements necessary for plants to grow and develop (Craigie 2011). Vast seaweed resources off the coast of South Africa, of which the kelp *Ecklonia maxima* is the dominant species, are a renewable source of raw material with a range of uses. Seaweeds differ as to their chemical composition and, as a result, have got properties (Bai et al. 2007). *E. maxima* is a species representing brown algae. It is most typically found along the southern coast of Africa, and Kelpak is the name of the product based on it (Khan et al. 2009). There are many foreign works whose authors report a favourable influence of Kelpak on crop plant growth and development. However, Ferreira and Lourens (2002) demonstrated in their studies that the product had no positive effect on plant performance. It should also be noted that most of
these studies were conducted under controlled conditions of a greenhouse. Only few field experiments have been conducted so far (Jensen 2004; Ciepiel et al. 2013). The effect of the algae extract is conditioned by many factors, including the crop plant species (Zodape 2001; Ferreira and Lourens 2002). Scientific literature lacks reports on the efficiency of natural biostimulants in fodder grass cultivation (Godlewska and Ciepiel 2013; Ciepiel and Godlewska 2014).

Grasslands produce the cheapest forage which is rich in nutrients (Jankowska-Huflejt and Wróbel 2008). The criteria of evaluating the fodder’s nutritional value include structural and non-structural carbohydrates and lignin content. Either an excess or shortage of these components in fodder should be avoided (Podkówka and Podkówka 2006).

Materials and methods

A field experiment was arranged as a randomised sub-block design (split-split plot) with three replicates at the Siedlce Experimental Unit of the Siedlce University of Natural Sciences and Humanities (Poland) in late April 2009. The plot area was 10 m². The soil of the experimental site represents average soils, Hortic Anthrosol (WRB). Prior to the experiment set-up, the characteristics of the soil were as follows: neutral pH (pH in 1n KCl—7.2), high humus content (3.78 %), high available phosphorus and magnesium contents (P₂O₅—900 mg kg⁻¹, Mg—84 mg kg⁻¹) and average total nitrogen and available potassium contents (N—1.8 g kg⁻¹ d.m., K₂O—190 mg kg⁻¹). Soil chemical analysis was carried out at an accredited laboratory of the Chemical and Agricultural Research Laboratory in Warsaw (Poland). Available phosphorus and potassium in the soil were extracted by means of the Egner-Riehm method (Staugaitis and Rutkauskiene 2010) and available magnesium—using the Schachtschabel method (Staugaitis and Rutkauskiene 2010). Phosphorus was determined by the colorimetric method, total nitrogen by the Kjeldahl method and potassium and magnesium by the atomic absorption spectrophotometry AAS.

The following factors were examined:

- *E. maxima* extract biostimulant with the trade name Kelpak SL applied at 2 dm³ ha⁻¹ and a control—no biostimulant
- Nitrogen application rates 50 and 150 kg ha⁻¹ and a control (0 kg ha⁻¹)

Table 1 Content of cellulose in orchard grasses and Braun’s festulolium (g kg⁻¹ s.m.) depending on biostimulator, nitrogen dose and cut (mean from years 2010–2012)

| Cut | N dose (kg N ha⁻¹) | Species of grass | Mean | Species of grass | Mean |
|-----|-------------------|------------------|------|------------------|------|
|     |                   | Orchard grasses   |      | Braun’s festulium|      |
|     |                   | Treatment | I | II | I | II | Treatment | I | II |
| 1   | 0                 | 325 a | 304 b | 323 a | 295 b | 324 a | 300 b | 315 A | 309 A | 312 A |
|     | 50                | 318 a | 300 b | 305 a | 289 b | 311 a | 294 b | 309 A | 297 A | 303 A |
|     | 150               | 314 a | 295 b | 286 a | 265 b | 300 a | 280 b | 304 A | 275 B | 290 B |
| 2   | 0                 | 315 a | 297 b | 318 a | 284 b | 316 a | 291 b | 306 A | 301 A | 303 A |
|     | 50                | 311 a | 295 b | 294 a | 281 a | 303 a | 288 b | 303 A | 288 B | 295 A |
|     | 150               | 303 a | 287 b | 278 a | 263 a | 290 a | 275 b | 295 A | 271 C | 283 B |
| 3   | 0                 | 315 a | 292 b | 300 a | 281 b | 308 a | 287 b | 304 A | 290 A | 297 A |
|     | 50                | 305 a | 287 b | 291 a | 272 b | 298 a | 280 b | 296 A | 282 A | 289 A |
|     | 150               | 289 a | 274 b | 271 a | 255 b | 280 a | 264 b | 282 B | 263 B | 272 B |
| Mean| 0                 | 318 a | 298 b | 314 a | 287 b | 316 a | 292 b | 308 A | 300 A | 304 A |
|     | 50                | 311 a | 294 b | 297 a | 281 b | 304 a | 287 b | 303 A | 289 B | 296 B |
|     | 150               | 302 a | 285 b | 278 a | 261 b | 290 a | 273 b | 294 B | 270 C | 282 C |
| 1   | Mean              | 319 a | 299 b | 305 a | 283 b | 312 a | 291 b | 309 A | 294 A | 301 A |
| 2   |                   | 309 a | 293 b | 297 a | 276 b | 303 a | 285 b | 301 B | 286 B | 294 B |
| 3   |                   | 303 a | 284 b | 288 a | 269 b | 295 a | 277 b | 294 C | 278 C | 286 C |
| Mean|                   | 310 a | 292 b | 296 a | 276 b | 303 a | 284 b | 301 a | 286 b | 294 |

I refers to control (without biostimulant). II refers to treatment with biostimulant (2 dm³ ha⁻¹). Different small letters within the same line indicate significant differences. Values in columns for individual factors indicated with different, capital letters differ significantly.
• Pure stands of grass species grown in monoculture
  – Orchard grass (*Dactylis glomerata*), cv. Amila
  – Braun’s festulolium (*Festulolium braunii*), cv. Felopa.

The growth stimulant applied in the experiment is an extract from the fastest growing seaweed (kelp) *E. maxima* harvested off the coast of South Africa. The extract contains, among others, the natural plant hormones auxins (11 mg l⁻¹) and cytokinins (0.03 mg l⁻¹). The commercial name of the stimulant is Kelpak SL, and it is manufactured by Kelp Products (Pty) Ltd. P.O. Box 325, Simon’s Town, the Republic of South Africa.

The first year of experiment was an introductory phase when only one nitrogen rate was applied and no biostimulant was used. It was a preliminary period when three cuts were performed to remove weeds. After the second cut, mineral fertilisers were applied to all the plots at the following rates: 30 kg ha⁻¹ N (ammonium nitrate) and 30 kg ha⁻¹ K₂O (potassium salt). No phosphorus was applied as the soil was rich in available P.

Over the study period (2010–2012), the cutting regime was three harvests per year. Ammonium nitrate was applied three times per year. The total nitrogen amount was split into three equal rates which were applied before each cutting. Phosphorus and potassium needs of the grass were calculated, taking into account the expected dry matter yields, the appropriate mineral (from the rumen nutrition standpoint) contents of hay and soil P and K availability. Moreover, to determine phosphorus and potassium application rates, coefficients given by Fotyma and Mercik (1995) were used to convert the amounts of the nutrients taken up by grass yields into the rates of phosphorus and potassium fertilisers. Phosphorus and potassium fertilisation was applied to all the plots. Phosphorus was applied once as triple superphosphate at a rate of 40 kg ha⁻¹ P₂O₅ in the spring. The amount of potassium (160 kg ha⁻¹ K₂O) was split into three equal rates and applied prior to each cutting as 60 % potash salt. The seaweed extract was sprayed as an aqueous solution, the rate was 2 dm³ of biostimulant per hectare diluted in water to 400 dm³. The spraying was performed before each cutting: the first application was 3 weeks before the first cutting, the second one 2 weeks after the first harvest and the last one 3 weeks after the second harvest.

During each harvest, 0.5 kg green matter samples of grasses were taken from each plot to carry out chemical

| Cut | N dose (kg N ha⁻¹) | Species of grass | Mean | Species of grass | Mean |
|-----|-------------------|------------------|------|------------------|------|
|     |                   | Orchard grasses  |      | Braun’s festulolium |      |
| I   | II                |                  | I    | II               |      |
| I   | II                |                  | I    | II               |      |
| 1   | 0                 | 218 a            | 201 b| 194 a            | 188 a|
|     | 50                | 208 a            | 191 b| 195 a            | 186 a|
|     | 150               | 155 a            | 135 b| 149 a            | 128 b|
| 2   | 0                 | 224 a            | 204 b| 214 a            | 193 b|
|     | 50                | 214 a            | 201 b| 202 a            | 191 b|
|     | 150               | 207 a            | 196 b| 196 a            | 174 b|
| 3   | 0                 | 221 a            | 202 b| 193 a            | 182 b|
|     | 50                | 207 a            | 195 b| 201 a            | 187 b|
|     | 150               | 186 a            | 154 b| 177 a            | 145 b|
| Mean|                   | 221 a            | 202 b| 200 a            | 187 b|
|     | 50                | 209 a            | 196 b| 199 a            | 188 a|
|     | 150               | 183 a            | 161 b| 174 a            | 149 b|
| 1   | Mean              | 193 a            | 175 b| 179 a            | 167 a|
| 2   | 215 a             | 200 b            | 204 a| 186 b            | 171 b|
| Mean| 205 a             | 183 b            | 190 a| 171 b            | 177 b|
| Mean| 204 a             | 186 b            | 191 a| 175 b            | 181 b|

1 refers to control (without biostimulant). II refers to treatment with biostimulant (2 dm³ ha⁻¹). Different small letters within the same line indicate significant differences. Values in columns for individual factors indicated with different, capital letters differ significantly.
analyses. The samples were left to dry in a ventilated room. The airy dry matter was shredded and ground. The obtained material was subjected to chemical analysis to determine dry matter, cellulose, hemicellulose, lignin, total protein, crude ash and crude fat. The above-mentioned components were determined by near infrared spectroscopy (NIRS) using a NIRFlex N-500 spectrometer and ready-to-use INGOT® calibration applications. INGOT® is a set of Universal NIR calibrations (adapter to the NIRFlex N-500 data format) for the analysis of raw materials and finished products, e.g. grass.

Non-structural carbohydrates were calculated following Virkajärvi et al. (2012):

\[
\text{non-structural carbohydrates} = 1000 - (\text{total protein} + \text{crude ash} + \text{crude fat} + \text{cellulose} + \text{hemicelluloses} + \text{lignin})
\]

The program STATISTICA (data analysis software system) version 10 (www.statsoft.com) was used to statistically analyse the results. Significance of differences between means for the experimental factors was checked using Tukey’s test at the significance level of \( \alpha \leq 0.05 \).

### Results and discussion

Fodder grass species differ substantially as to carbohydrate and lignin contents as a result of an impact of numerous biological, ecological and anthropogenic factors, in particular cultivation practices. Cellulose content in the tested plants was 293.7 g kg\(^{-1}\) DM (Table 1) regardless of the species, biostimulant application, fertilisation and cut. Statistical analysis of the obtained results demonstrated a significant influence of all the experimental factors on cellulose content in the plant material. An application of marine algae extract reduced the cellulose content of both the grass species. An interaction of biostimulant and nitrogen fertilisation was unidirectional: an application of Kelpak significantly reduced

| Cut | N dose (kg N ha\(^{-1}\)) | Species of grass | Mean | Species of grass | Mean |
|-----|-----------------|-----------------|------|-----------------|------|
|     |                 | Orchard grasses |      | Braun’s festulolium |      |
|     |                 | Treatment | I     | II     | I     | II     | I     | II     |
| 1   | 0               |            | 48.0 a | 44.5 b | 43.1 a | 38.8 b | 45.6 a | 41.7 b | 46.2 A | 41.0 A | 43.6 A |
|     | 50              |            | 46.0 a | 43.3 a | 42.0 a | 37.5 b | 44.0 a | 40.4 b | 44.7 A | 39.8 A | 42.2 A |
|     | 150             |            | 43.5 a | 40.4 b | 38.4 a | 36.0 a | 41.0 a | 38.2 b | 42.0 B | 37.2 B | 39.6 B |
| 2   | 0               |            | 50.0 a | 46.2 b | 47.1 a | 40.3 b | 48.5 a | 43.3 b | 48.1 A | 43.7 A | 45.9 A |
|     | 50              |            | 48.1 a | 44.8 b | 44.2 a | 38.7 b | 46.2 a | 41.7 b | 46.5 A | 41.4 B | 44.0 B |
|     | 150             |            | 45.6 a | 41.3 b | 40.2 a | 37.2 b | 42.9 a | 39.3 b | 43.5 B | 38.7 C | 41.1 C |
| 3   | 0               |            | 45.6 a | 42.1 b | 41.0 a | 37.0 b | 43.3 a | 39.5 b | 43.8 A | 39.0 A | 41.4 A |
|     | 50              |            | 43.9 a | 40.8 b | 39.5 a | 34.7 b | 41.7 a | 37.8 b | 42.4 A | 37.1 AB | 39.8 A |
|     | 150             |            | 40.6 a | 37.2 b | 37.2 a | 33.1 b | 38.9 a | 35.2 b | 38.9 B | 35.2 B | 37.0 B |
| Mean|                 |            | 47.8 a | 44.2 b | 43.7 a | 38.7 b | 45.8 a | 41.5 b | 46.0 A | 41.2 A | 43.6 A |
|     | Mean            | Orchard grasses | 45.8 a | 42.7 b | 41.2 a | 37.5 b | 43.5 a | 40.0 b | 43.5 A | 39.4 B | 42.0 B |
|     | Mean            | Braun’s festulolium | 45.8 a | 42.7 b | 41.2 a | 37.5 b | 43.5 a | 40.0 b | 43.5 A | 39.4 B | 42.0 B |

I refers to control (without biostimulant). II refers to treatment with biostimulant (2 dm\(^3\) ha\(^{-1}\)). Different small letters within the same line indicate significant differences. Values in columns for individual factors indicated with different, capital letters differ significantly.
cellulose content of grasses at all the nitrogen rates, least cellulose (273 g kg\(^{-1}\) DM) being determined in plants sampled in the plots where an application of Kelpak was accompanied by 150 kg N ha\(^{-1}\). Moreover, cellulose content decreased significantly (by 6.33 %, on average) in all the cuts and when the algae extract had been applied. Nitrogen fertilisation influenced the content in the grasses examined, too. When nitrogen rate was increased from 0 to 150 kg ha\(^{-1}\) and from 50 to 150 kg ha\(^{-1}\), cellulose content determined in the dry matter of the plants decreased significantly. Cellulose is the main component of crude fibre. According to Szkutnik et al. (2012), high nitrogen rates reduce (by 5 %) the amount of crude protein in grasses.

The results of the study discussed here indicated that cellulose contents were different in both the plant species. Braun’s festulolium contained by 5.08 % less cellulose than orchard grass. Kozłowski and Śwędryński (2001) have stated that orchard grass represents grasses which are high in cellulose and contains between 10 and 20 % more cellulose compared with the parental species of Braun’s festulolium—meadow fescue and annual ryegrass. Cellulose content in the tested grasses was also closely related to cuts. During the growing season, the content significantly declined in successive cuts. A similar association was reported by Golińska and Kozłowski (2006) who studied reed canary grass. The lowest structural carbohydrate level was probably due to poorer plant foliage.

The results of this study indicated that there was a uniform, significant effect of the biostimulant and nitrogen fertilisation on hemicellulose and lignin contents in the grass species examined (Tables 2 and 3). An application of Kelpak significantly reduced hemicellulose and lignin contents in both the grass species, regardless of the remaining experimental factors. Statistical analysis revealed a significant interaction of the biostimulant and nitrogen fertilisation: an application of Kelpak significantly reduced the amounts of both hemicellulose and lignin in the plants at each of the nitrogen rates, by 8.90 and 8.77 %, respectively. Least hemicellulose (131.3 g kg\(^{-1}\) DM) and lignin (38.2 g kg\(^{-1}\) DM) were determined in Kelpak-treated and nitrogen-fertilised grasses when the N rate was 150 kg ha\(^{-1}\). Also, Poisae al. (2011) reported a significant interaction between lignin content and nitrogen fertilisation rate.

The grass species tested in the experiment had significantly different hemicellulose and lignin contents regardless of Kelpak application, nitrogen rates and cuts. The study discussed here showed that Braun’s festulolium had the

### Table 4

| Cut | N dose (kg N ha\(^{-1}\)) | Species of grass | Mean | Species of grass | Mean |
|-----|--------------------------|------------------|------|------------------|------|
|     |                          | Orchard grasses  |      | Braun’s festulolium |      |
|     |                          | Treatment |      | Treatment |      |
|     |                          | I | II | I | II |
| 1   | 0                        | 214 a | 243 b | 239 a | 261 b | 227 a | 252 b | 229 A | 250 A | 240 A |
|     | 50                       | 208 a | 236 b | 232 a | 255 b | 220 a | 245 b | 222 A | 243 AB | 233 A |
|     | 150                      | 191 a | 218 b | 222 a | 246 b | 207 a | 232 b | 205 B | 234 B | 219 B |
| 2   | 0                        | 171 a | 200 b | 195 a | 216 b | 183 a | 208 b | 186 A | 205 A | 196 A |
|     | 50                       | 164 a | 183 b | 189 a | 211 b | 176 a | 197 b | 173 B | 200 A | 187 A |
|     | 150                      | 152 a | 175 b | 167 a | 200 b | 159 a | 187 b | 159 B | 183 B | 173 B |
| 3   | 0                        | 196 a | 237 b | 213 a | 255 b | 205 a | 246 b | 216 A | 234 A | 225 A |
|     | 50                       | 191 a | 208 a | 208 a | 226 b | 199 a | 217 a | 199 B | 217 B | 208 B |
|     | 150                      | 175 a | 199 b | 192 a | 216 b | 184 a | 208 b | 187 C | 204 C | 196 C |
| Mean|                          | 194 a | 227 b | 216 a | 244 b | 205 a | 236 b | 210 A | 230 A | 220 A |
|     | 50                       | 188 a | 209 b | 210 a | 231 b | 199 a | 220 b | 198 A | 220 A | 209 B |
|     | 150                      | 173 a | 197 b | 194 a | 221 b | 183 a | 209 b | 185 B | 207 B | 196 C |
| Mean|                          | 205 a | 232 b | 231 a | 254 b | 218 a | 243 b | 218 A | 243 A | 231 A |
| 2   |                          | 162 a | 186 b | 184 a | 209 b | 173 a | 197 b | 174 B | 196 B | 185 B |
| 3   |                          | 187 a | 215 b | 204 a | 233 b | 196 a | 224 b | 201 C | 219 C | 210 C |
| Mean|                          | 185 a | 211 b | 206 a | 232 b | 196 a | 221 b | 198 a | 219 b | 209 |
highest nutritional value as it contained by 6.3 and 10.9 % less, respectively, hemicellulose and lignin compared with orchard grass. Also, Borowiecki (2002) has reported that orchard grass contained more structural carbohydrates and lignin than Braun’s festulolium. Hemieellulose and lignin concentrations differed significantly depending on the cut. Most hemicellulose and lignin, respectively, 201.4 and 43.6 g kg⁻¹ DM, were determined in second-cut grasses. Similar findings were reported by Golisińska and Kozłowski (2006).

Non-structural carbohydrates which are components of the inner part of plant cells determine the nutritional value and taste of fodder plants as well as their usability type and suitability for a given fodder production technology (Wilman and Riley 1993; Downing and Gamroth 2007). Average non-structural sugars in the grasses tested reached the level of 208.5 g kg⁻¹ DM (Table 4). Statistical analysis demonstrated a significant effect of the biostimulant on sugar concentration in the grasses. According to Joubert and Lefranc (2008), active substances in sea algae extracts act as plant activators, thus inducing changes in the chemical composition of plants sprayed with these extracts. Kelpak significantly (by 11 %) increased non-structural carbohydrates, regardless of the remaining experimental factors. Also, studies conducted by Pacholeczak et al. (2012) have demonstrated that a sea alga extract significantly increased non-structural sugars; however, no literature evidence for grasses has been found.

Increasing nitrogen rates significantly reduced non-structural carbohydrates in the tested grass species sampled from each cut. Similar results for orchard grass have also been reported by Kozłowski et al. (2001) as well as Ciepiela (2004). Such a response may be due to increased accumulation of protein compounds which require carbohydrates to be formed. Grzelak (2010) has pointed out that sugar content of plants depends on many factors including plant species, which was confirmed in this study. Of the two grasses, Braun’s festulolium contained significantly more non-structural carbohydrates, regardless of an application of Kelpak, nitrogen rate and cut. Also, Downing and Gamroth (2007) have reported similar findings for Braun’s festulolium compared with orchard grass. This fact indicates that Braun’s festulolium is more nutritious and tasty than orchard grass.

Similar to Kozłowski et al. (2001), seasonal changes in the amount of grass carbohydrates were observed. Most non-structural carbohydrates were found in first-cut grass and least in second-cut grass, which was due to more intense respiration of plants occurring at high temperatures, as confirmed by other authors (Ciepiela 2004; Watts 2008). Also, Downing and Gamroth (2007) have reported that concentration of non-structural carbohydrates in grasses decreases as air temperature increases.

Conclusions

1. An application of the biostimulant Kelpak SL significantly reduced cellulose, hemicellulose and lignin contents and significantly increased non-structural carbohydrates in the tested plants.
2. Increasing nitrogen rates significantly decreased cellulose, hemicellulose, lignin and non-structural carbohydrate contents.
3. Braun’s festulolium had a better nutritional value than orchard grass as it was lower in cellulose, hemicellulose and lignin but higher in non-structural carbohydrates compared with orchard grass.
4. The aforementioned contents in the grasses differed significantly, depending on the cut. Most cellulose and non-structural carbohydrates were found in first-cut grass and most hemicellulose and lignin in second-cut grass.

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References

Bai NR, Banu NRL, Prakash JW, Goldi SJ (2007) Effects of Asparagopsis taxiformis extract on the growth and yield of Phaseolus aureus. J Basic Appl Biol 1:6–11
Borowiecki J (2002) The effect of nitrogen fertilization on fielding and feeding value of Festulolium braunii var. Felopa. Pam Pul 131:39–48
Ciepiela GA (2004) Reaction of some grass species on the nitrogen fertilization applied in urea solution and in ammonium nitrate. Dissertation no 76, Publication of the University of Podlasie, Siedlce. (In Polish)
Ciepiela GA, Godlewska A (2014) Changes in protein compounds and monosaccharides in select grass species following application of a seaweed extract. Pol J Environ Stud 23(1):29–35
Ciepiela GA, Godlewska A, Jankowska J (2013) The effect of biostimulant on yields of mixed grass/red clover stands and chlorophyll content in crop plant leaves under different nitrogen fertilisation regimes. Fresenius Environ Bull 22(12b):3700–3708
Craigie JS (2011) Seaweed extract stimuli plant science and agriculture. J Appl Physiol 23:371–393
Downing T, Gamroth M (2007) Nonstructural carbohydrates in cool-season grasses. Oregano State University, Extension Service. Special Report 1079-E:1–6
Ferreira MI, Lourens AF (2002) The efficacy of liquid seaweed extract on the field canola plants. S Afr J Plant Soil 19(3):159–161
Fotyma M, Merick S (1995) Fertilization and crop technologies. [in]: Agricultural Chemistry. State Scientific Publishers, Warsaw:233–295
Godlewska A, Ciepiela GA (2013) The effect of natural growth regulators obtained from Ecklonia maxima and mineral nitrogen on true protein and simple sugar contents of Dactylis glomerata L. and...
Festulolium braunii (K. richt.) A. camus. Turk J Field Crops 18(2): 247–253

Golińska B, Kozłowski S (2006) Variation in the occurrence of organic and mineral compounds in Phalaris arundinacea. Ann UMCS Sec E 61:353–360 (In Polish) (abstract in English)

Grzelak M (2010) The productivity and fodder value of hay from extensively utilised Noteć River Valley Meadows. Nauka Przyroda Technol 4(1):1–8 (In Polish) (abstract in English)

Jankowska-Huflejt H, Wróbel B (2008) Evaluation of usefulness of forages from grasslands in livestock production in examined organic farms. J Res Appl Agric Eng 53(3):103–108 (In Polish) (abstract in English)

Jankowski K, Jankowska J, Ciepiela GA, Sosnowski J, Wiśniewska-Kadżajan B, Kolczarek R (2014) The efficiency of nitrogen from fertilizers in orchard grass cultivated in pure sowing or with the legumes. Rom Agric Res 31:1–7

Jensen E (2004) Seaweed: fact or fancy? Organic Broadcaster 12

Joubert JM, Lefranc G (2008) Seaweed phyto stimulants in agriculture: recent studies on mode of action two types of products from algae: growth and nutrition stimulants and stimulants of plant Demence reactions. Book of abstracts: Biostimulators in modern agriculture. Warsaw p.16

Khan W, Rayirath UP, Subramanian S, Jithesh MN, Rayorath P, Hodges DM, Critchley AT, Norrie J, Prithiviraj B (2009) Seaweed extracts as biostimulants of plant growth and development. J Plant Growth Regul 28:386–399

Kozłowski S, Świędrzyski A (2001) Structural carbohydrates and lignins vs. use value of meadow plants. Pam Pul 125:139–146 (In Polish) (abstract in English)

Kozłowski S, Golińska B, Goliński P (2001) Sugars vs. use value of meadow plants. Pam Pul 125:131–138 (In Polish) (abstract in English)

Masny A, Basak A, Żurawicz E (2004) Effects of foliar application of Kelpak SL and Gaëmar bm 86 preparations on yield and fruit quality in two strawberry cultivars. J Fruit Ornam Plant Res 12:23–27

Matysiak K, Adamczewski K (2006) Influence of bioregulator Kelpak on field of cereals and other crops. P rog Plant Protect 46(2):102–108 (In Polish)

Matysiak K, Kaczmarek S, Krawczyk R (2011) Influence of seaweed extracts and mixture of humic and fulvic AIDS on germination and growth of Zea mays L. Acta Sci Pol Agric 10(1):33–45

Pachołczak A, Szydło W, Jacygard E, Federowicz M (2012) Effect of auxins and the biostimulator algaminoplant on rhizogenesis in stem cuttings of two dogwood cultivars (Cornus alba ‘Aurea’ and ‘Elegantissima’). Acta Sci Pol Hortoru 11(2):93–103

Podkówska W, Podkówska Z (2006) Dry matter, organic matter digestibility, ADF and NDF content in some corn varieties of PIONNER company harvested for silage production from 1998–2033. Pam Pul 142:363–372 (In Polish) (abstract in English)

Pośn L, Adamovič A, Platač R, Teirmieka Ŕ (2011) Evaluation of the factors that affect the lignin content in the reed canary grass (Phalaris arundinacea L.) in Latvia. Word Renewable Energy Congress 8–13 May 2011, Linköping, Sweden, Bioenergy Technology: 224–231

Russell CL (2002) Kelp based growth stimulants—science or snake oil? Internal Technical Biuletin of Cobbett Pty Ltd (CD).

Staugaitis G, Rutkauskienė R (2010) Comparison of magnesium determination methods as influenced by soil properties. Zemdirbyste-Agriculture 3(97):105–116

Szukutnik J, Kacorzyk P, Szewczyk W (2012) The content change of total protein and crude fibre depending on the dose of fertilization and phanological phase of grasses. Grassland Sci Poland 15:185–191 (In Polish) (abstract in English)

Virkajärvi P, Saarijärvi K, Rinne M, Saastamoinen M (2012) Grass physiology and its relations to nutritive value in feeding horses. Forages and grazing in horse nutrition: 17–43

Watts KA (2008) Carbohydrates in forage: what is a safe grass? Proc. Kentucky Equine Research, advances management of gastrointestinal and metabolic diseases. Lexington, 1–11

Wilman D, Riley JA (1993) Potential nutritive value of a wide range of grassland species. J Agric Sci 120:43–49

Zodape ST (2001) Seaweeds as fertilizer. J Sci Ind Res 60(5):378–382