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Effects of polyethylene film covering the greenhouse, nitrogen fertiliser form, and foliar nutrition on the yield and quality of lettuce

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ABSTRACT

This study investigates the effects of two types of polyethylene films covering the greenhouse, differing in PAR transmittance, as well as two forms of nitrogen fertiliser (100% N-NO_3 *vs.* 57% N-NO_3 + 43% N-NH_4), and the use of foliar nutrition on the quality and yield of lettuce grown in the spring and summer-autumn seasons. Lettuce was grown on rockwool in a film greenhouse divided into two parts, each covered with one type of film. Three times per season the plants were sprayed with a solution of molybdenum, benzyladenine, urea with molybdenum, urea with benzyladenine, and the three substances combined. The yields were examined for dry matter, nitrates, ammonia nitrogen, protein nitrogen, soluble sugars, vitamin C, and macronutrients (phosphorus, potassium, calcium and magnesium). In both seasons, lettuce cultivated in the greenhouse covered with film having a higher PAR transmittance resulted in heavier heads and contained significantly lower levels of nitrates, NH_4^+, P and Mg. The effect of plot (type of film) on vitamin C content depended on the season. The form of nitrogen fertiliser influenced dry matter, vitamin C, protein nitrogen, P and Mg contents; in the summer-autumn season it also affected head weight. The plants grown on a nitrate medium produced a higher single head mass and accumulated a larger amount of nitrates than those cultivated on a nitrate-ammonia medium. No effects were observed of foliar nutrition with salt solutions on the yield and quality of lettuce in either season.

Key words: biological value, light intensity, nitrates, soilless culture

INTRODUCTION

Plant yield and its biological value (levels of vitamin C, minerals, protein, sugars) depend on various factors, among them plant genetics, light intensity, fertilisation, and soil conditions. These factors also have an effect on the amounts of compounds that are harmful to human health, such as nitrates. Light intensity varies greatly according to the climatic zone, season of the year, cloud cover, and anthropogenic factors, e.g. the cleanness and thickness of windows in a greenhouse or the type of film covering the greenhouse. As observed by Piróg (1993), reducing the light intensity by 1% resulted in a 1% decrease in the yield of plants. This is due to the fact that in the process of photosynthesis, compounds forming the biomass of plants are produced and the energy necessary for metabolic processes is released.

The level and form of N are among the most important fertilizer factors for the yield and biological value of plant. Numerous studies have shown that fertilisation with reduced or nitrate-ammonia forms of nitrogen is the most effective way of decreasing the nitrate content of vegetable plants without affecting their yields (Campbell 1999, Kronzucker et al. 1999). Reduced forms of nitrogen can be directly built in organic compounds. Moreover, both forms have an effect on the activity of nitrate reductase (Langellan and Troelstra 1992).

Research into the effects of foliar nutrition on plant yields and nitrate contents have not given unequivocal results. In a study by Smoleń and Sady (2005), carrot fertilised with benzyladenine showed higher yields, but foliar nutrition with benzyladenine combined with urea and molybdenum resulted in lower yields. Kowalska (1998) found that foliar nutrition with urea reduced the nitrate content of lettuce, while other authors (Bednarz et al. 1998, Smoleń et al. 2006) reported increased levels of nitrates in plants fed foliarly by urea.

The aim of this study was to determine the effect of the type of film covering the greenhouse and N-fertilizer form as well as foliar nutrition on yield and quality of lettuce grown in different vegetation seasons.

MATERIAL AND METHODS

The experiment was conducted in the spring and summer-autumn seasons of 2005. 'Melodion F_1' lettuce was grown on rockwool slabs placed in channels using a drip fertigation system without recycling. The growing medium contained (mg dm^{-3}): N – 150, P – 50, K – 200, Ca – 150, Mg – 30, Fe – 1.22, Cu – 0.09, Zn – 0.09, Mn – 0.47, B – 0.17, Mo – 0.03 and pH were maintained in the ranges 6.0-6.2, and EC 1.8-2.0 mS cm^{-1}.

Plants at a stage of four true leaves, produced in peat plugs (∅ 5 cm), were placed on 20 × 7.5 × 100 cm Master (Grodan) rockwool slabs. Each slab contained three plants.

The cultivation was carried out in a film greenhouse divided into two parts. One part was covered with Ginegar film (film I) and the other with Gemme 4S film (film II). The two films differed in light transmittance (film I – 86%, film II – 90%) and light diffusion (film I – 50%, film II – 15%) (according to the producer). In addition, Gemme 4S transmitted 30% more photosynthetically active radiation (PAR) than Ginegar. In each part of the greenhouse there were two sets of three 20 m long channels independently fed with media containing different forms of nitrogen: solely nitrate nitrogen (100% $N\text{-}NO_3$), or nitrate-ammonia (57% $N\text{-}NO_3$ and 43% $N\text{-}NH_4$). Each channel was divided into six parts (with nine plants each), which were treated by a different kind of solution used in foliar nutrition or foliar treatment:

1. control (without foliar nutrition),
2. molybdenum solution (1 ppm),
3. benzyladenine solution (BA; 5 ppm; foliar treatment),
4. solution of urea (1%) and molybdenum (1 ppm),
5. solution of urea (1%) and benzyladenine (BA, 5 ppm),
6. solution of urea (1%), molybdenum (1 ppm) and benzyladenine (BA, 5 ppm).

For each treatment there were three replications, with channels being the replicates.

Each season, the plants received foliar nutrition on three dates: seven and fourteen days after the seedlings were placed on slabs, and eight days before harvest. The fertiliser solutions were distributed using a manual sprayer until the leaves were completely wet. At the time of spraying, the plants from neighbouring treatments were isolated with polystyrene foam shields.

The yields were evaluated on the basis of the weight (g) of one head. Six lettuce heads were sampled per treatment, then a quarter was cut out of each head and broken up. The material was analysed for dry matter, nitrates, ammonia nitrogen, protein nitrogen, soluble sugars, P, K, Ca and Mg. Nitrates and ammonia nitrogen were determined by using an 'Orion' ion-selective electrode following extraction with aluminium sulphate; protein nitrogen using the Kjeldahl method (Ostrowska et al. 1991), soluble sugars with the anthrone method (Yemm and Wills 1954), vitamin C with the Tillmans method (Krełowska-Kułas 1993) and P, K, Ca and Mg were extracted with 2% acetic acid and determined by means of colourimetry (P) or atomic absorption (K, Ca, Mg).

All data were subjected to a three-way analysis of variance, considering the following experimental factors:

1. type of film covering the greenhouse,
2. form of nitrogen fertiliser,
3. type of solution used in foliar nutrition or foliar treatment.

The differences between the means were analysed by Fischer's test (LSD) at a significance level p = 0.05.

RESULTS

A lettuce head weighed 272 g on average in the spring season and 202 g in the summer-autumn period (Tabs 1 and 2). In both seasons, plants cultivated in a greenhouse covered with Gemme 4S film produced significantly heavier heads than those grown under a Ginegar film greenhouse: the respective weights were 284 and 218 g compared to 259 and 185 g. The weights of the heads were consistently greater in treatments fertilised with nitrate nitrogen than in those receiving nitrate-ammonia fertiliser; the differences, however, were statistically significant only for the summer-autumn season of cultivation. Foliar nutrition with a benzyladenine + urea + molybdenum solution and with a benzyladenine solution resulted in the heaviest head weights (280 and 285 g, respectively) in the spring season. No effects of foliar nutrition were observed in the summer-autumn season.

The dry matter content of plants ranged from 6.16 to 6.76% in spring, and from 6.03 to 6.32% in summer-autumn (Tabs 1 and 2). In both seasons, only the type of greenhouse film and the form of nitrogen fertiliser (NO_3 *vs.* NO_3/NH_4) had an effect on dry matter levels,

Table 1. Effect of type of tunnel film, nitrogen form and foliar nutrition on yield and content of selected nutrients in lettuce grown in rockwool (spring season)

Treatments		Head weight (g)	Dry matter (%)	Nitrates (mg kg^{-1} f.m.)	NH_4^+ (mg kg^{-1} f.m.)	N (% d.m.)	Soluble sugars (% f.m.)	Vit. C (mg 100 g^{-1} f.m.)	P (% d.m.)	K (% d.m.)	Ca (% d.m.)	Mg (% d.m.)
Type film	I*	259	6.16	361.57	189.41	3.58	1.30	16.03	0.36	4.65	1.03	0.37
	II	284	6.76	131.08	69.69	3.20	1.59	21.63	0.30	3.88	1.08	0.26
Nitrogen form	NO_3	274	6.30	304.52	126.48	3.51	1.41	18.34	0.26	4.13	1.02	0.38
	NO_3/NH_4	269	6.61	188.14	132.62	3.27	1.48	19.32	0.41	4.39	1.09	0.25
Foliar nutrition	1**	261	6.47	213.62	125.75	3.30	1.38	19.49	0.35	4.28	1.05	0.29
	2	264	6.27	236.50	132.32	3.43	1.41	19.32	0.34	4.38	1.11	0.30
	3	285	6.40	229.05	135.62	3.28	1.50	17.99	0.33	4.26	1.05	0.28
	4	265	6.38	260.47	122.27	3.48	1.41	18.46	0.36	4.27	1.07	0.29
	5	276	6.62	255.03	130.25	3.44	1.55	18.32	0.31	4.14	1.03	0.42
	6	280	6.61	283.30	131.10	3.39	1.43	19.40	0.31	4.24	1.00	0.30
$LSD_{0.05}$ for:	Type film (A)	8.5	0.192	29.594	7.766	0.091	0.074	0.864	0.022	0.216	n.s.	0.098
	Nitrogen form (B)	n.s.	0.192	29.594	n.s.	0.091	n.s.	0.864	0.022	0.216	n.s.	0.098
	Foliar nutrition (C)	14.8	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	A × B	n.s.	0.271	41.853	10.982	0.129	0.105	n.s.	0.032	0.305	n.s.	n.s.
	A × C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	B × C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	A × B × C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

*I – tunnel covered with Ginegar film, II – tunnel covered with Gemme 4S film; **1 – control, 2 – Mo, 3 – BA, 4 – $CO(NH_2)_2$ + Mo, 5 – $CO(NH_2)_2$ + BA, 6 – $CO(NH_2)_2$ + Mo + BA; n.s. – non-significant

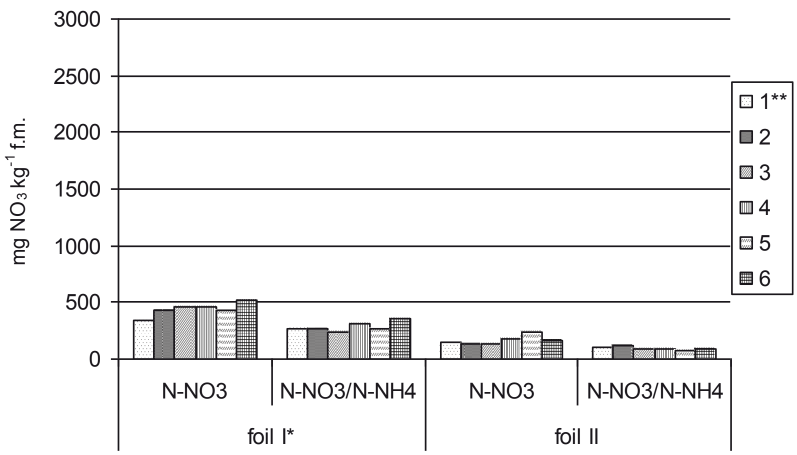
Table 2. Effect of type of tunnel film, nitrogen form and foliar nutrition on yield and content of selected nutrients in lettuce grown in rockwool (summer-autumn season)

Treatments		Head weight (g)	Dry matter (%)	Nitrates (mg kg^{-1} f.m.)	NH_4^+ (mg kg^{-1} f.m.)	N (% d.m.)	Soluble sugars (% f.m.)	Vit. C (mg 100 g^{-1} f.m.)	P (% d.m.)	K (% d.m.)	Ca (% d.m.)	Mg (% d.m.)
Type film	I*	185	6.03	1536.39	202.35	4.38	0.82	22.23	0.41	5.35	1.41	0.38
	II	218	6.32	1317.28	177.60	3.90	1.15	20.40	0.37	5.64	1.18	0.19
Nitrogen form	NO_3	213	6.00	1699.78	189.10	4.32	0.97	23.11	0.31	5.51	1.34	0.33
	NO_3/NH_4	190	6.35	1153.89	190.85	3.96	0.99	19.53	0.48	5.48	1.25	0.24
Foliar nutrition	1**	207	6.04	1426.00	182.60	4.04	0.96	20.28	0.41	5.64	1.23	0.28
	2	203	6.06	1765.50	187.12	3.96	0.93	20.83	0.41	5.48	1.30	0.28
	3	200	6.05	1195.67	199.63	4.17	0.95	22.39	0.37	5.79	1.38	0.29
	4	194	6.18	1467.83	185.97	4.30	0.95	21.19	0.42	5.43	1.33	0.29
	5	204	6.34	1421.92	191.40	4.14	1.02	21.90	0.38	5.39	1.29	0.28
	6	202	6.39	1284.08	193.13	4.22	1.09	21.31	0.37	5.24	1.25	0.28
$LSD_{0.05}$ for:	Type film (A)	12.3	0.169	212.114	15.383	0.217	0.072	1.612	0.022	0.261	0.145	0.029
	Nitrogen form (B)	12.3	0.169	212.114	n.s.	0.217	n.s.	1.612	0.022	n.s.	n.s.	0.029
	Foliar nutrition (C)	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	A × B	n.s.	n.s.	299.974	n.s.	0.307	n.s.	n.s.	0.031	0.369	0.206	0.041
	A × C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	B × C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	A × B × C	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

*,**Explanations: see Table 1

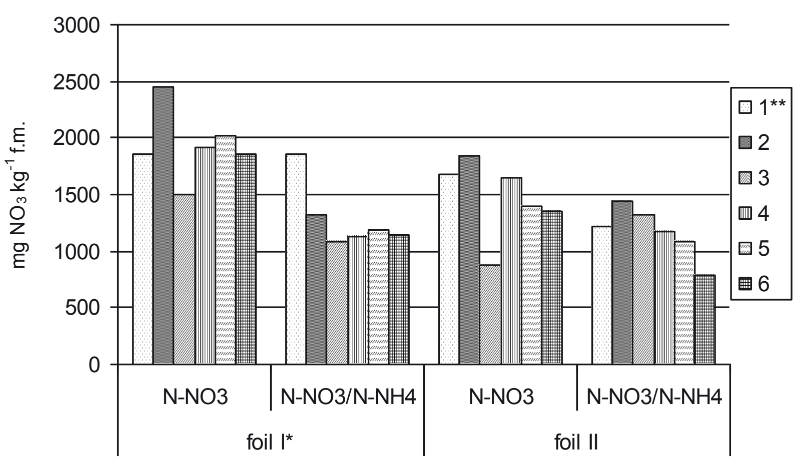
which were significantly higher for Gemme 4S film and the nitrate-ammonia medium. Worth mentioning is an interaction between the type of film and the form of nitrogen fertiliser in the spring season. Namely, in the part of the greenhouse covered with Gemme 4S film, the differences in dry matter content in plants due to the type of medium were bigger than in the part covered with Ginegar.

The lettuce contained a considerably larger amount of nitrates when cultivated in the summer-autumn season than in the spring (Tabs 1 and 2). In spring, plants cultivated under the Ginegar film accumulated over 2.5 times more nitrates than those grown under Gemme 4S. In the summer-autumn period the differences were smaller. In both seasons, using a nitrate-ammonia fertiliser resulted in significantly lower nitrate levels (188.14 and 1153.89 mg kg^{-1} f.m., respectively in spring and summer-autumn seasons) compared to plants grown on a nitrate medium (304.52 and 1699.78 mg kg^{-1} f.m., respectively). Interaction between the type of film and the form of nitrogen fertiliser had a significant impact on the nitrate content of plants in both seasons of cultivation (Figs 1 and 2). In the summer-autumn season, the differences in nitrate levels between the plants fertilised with nitrate nitrogen and those grown on a nitrate-ammonia medium were wider for the Ginegar film part of the greenhouse than in the part covered with Gemme 4S film. Foliar nutrition did not have a significant effect on the nitrate content of lettuce leaves in either season.



*I – tunnel covered with Ginegar foil, II – tunnel covered with Gemme S
**1 – control, 2 – Mo, 3 – BA, 4 – $CO(NH_2)_2$ + Mo, 5 – $CO(NH_2)_2$ + BA, 6 – $CO(NH_2)_2$ + Mo + BA

Figure 1. Effect of type of tunnel foil, nitrogen form and foliar nutrition on nitrate content in lettuce grown in rockwool (spring season)



*,**Explanations: see Fig. 1.

Figure 2. Effect of type of tunnel foil, nitrogen form and foliar nutrition on nitrate content in lettuce grown in rockwool (summer -autumn season)

Among the experimental factors, only the type of film influenced the ammonia nitrogen content of plants. Those growing under Ginegar film accumulated significantly more NH_4^+ than the plants growing under Gemme 4S, with the differences being substantial in the spring season, when the former accumulated 2.7 times more NH_4^+ than the latter.

The amount of protein nitrogen contained in the lettuce plants depended on the type of film and the form of nitrogen fertiliser. Employing Ginegar film and nitrate nitrogen led to higher levels of protein nitrogen in plants. There was a significant interaction between the two experimental factors. In the spring season, the differences in protein nitrogen contents due to the form of nitrogen fertiliser were more pronounced for plants covered with Gemme 4S film than for those covered with Ginegar, while in the summer-autumn season the opposite was true.

Lettuce plants cultivated in the spring season contained 0.5 times more soluble sugars than those grown in the summer-autumn period. In both seasons, the soluble sugar levels were higher when the greenhouse was covered with a film having a greater light transmittance (Gemme 4S). The other experimental factors produced non-significant effects.

The vitamin C content of plants depended only on the type of film and the form of nitrogen fertiliser. In the spring season, plants growing in the Gemme 4S film greenhouse were richer in this vitamin, while in the summer-autumn period, more vitamin C was found in plants from under the Ginegar film cover. The effects of nitrogen form on vitamin C content differed according to season: in the spring cultivation, the levels of vitamin C were higher for a nitrate-ammonia medium, whereas in the summer-autumn growing period, they were higher for a nitrate medium.

The type of film and form of N-fertiliser affected the P and Mg contents of lettuce. In both seasons, they were higher in plants grown in the Ginegar film-covered greenhouse. Supplying plants with a solution containing two forms of nitrogen resulted in a higher uptake of P and a smaller uptake of Mg ions compared to plants fed with nitrate nitrogen alone. There was a significant effect of the interaction of type of film covering the greenhouse and form of nitrogen fertilizer on the P content in the spring season, and on the Mg content additionally in the summer-autumn season.

The impacts of film type and nitrogen form on the K and Ca contents of lettuce depended on the cultivation period. In the spring season, plants grown in the greenhouse covered with Ginegar film had significantly higher K contents (4.65% d.m.) than those cultivated under Gemme 4S film (3.88% d.m.). In the summer-autumn season, the pattern was reversed. The form of nitrogen fertiliser had an effect on K levels in the spring cultivation - the plants supplied with both forms (NO_3/NH_4) contained significantly more K than those supplied with nitrate nitrogen. In the summer-autumn season, the effect of nitrogen form was non-significant. The Ca content did not depend on the two factors, except in the summer-autumn season when plants grown in the Ginegar film greenhouse accumulated more Ca than those cultivated under the Gemme 4S film cover.

Foliar nutrition had no effect on the P, K, Ca and Mg contents of lettuce plants in either season.

DISCUSSION

The yields of greenhouse-grown lettuce depended on the type of film covering the greenhouse. Using a film with a higher PAR transmittance (Gemme 4S) resulted in heavier head weights. Since solar radiation is the source of energy used in the process of photosynthesis by which assimilates are formed and chemical energy is produced that is responsible for the course of all metabolic processes taking place in plant cells, the presence of light constitutes the main factor determining the growth and weight increase of plants, while its deficit limits the yielding (Lawlor 2001). As shown by the results of the experiment, employing a film with a lower light transmittance (Ginegar) under the climatic conditions of Krakow led to decreased yields of lettuce both in the spring and summer-autumn cultivation.

The yields (head weights) differed between the seasons. In line with our findings, Escobar-Gutierrez et al. (2002) noted a higher yield when lettuce was cultivated in spring, i.e. a season with better light conditions, than in autumn. It is especially important to use a film with greater transmittance in periods with a smaller amount of light: in our experiment the Gemme 4S film increased the yields by 17.8% in the summer-autumn season, and only by 9.7% in the spring period.

The size of lettuce heads depended also on the form of nitrogen fertiliser: plants cultivated on a medium containing solely the nitrate nitrogen form attained heavier weights. Considering the findings made by Crawford and Glass (1998), suggesting that the optimal ratio between nitrate nitrogen and ammonia nitrogen in the cultivation of tomato should be 3:1, the decreased yields of lettuce plants grown on a medium containing both forms of nitrogen (NO_3/NH_4) may be attributed to a much larger proportion of ammonia nitrogen (53:47) used in our studies. Britto and Kronzucker (2002) report that higher concentrations of NH_4^+ cation in the root environment are toxic to plants.

Foliar nutrition with benzyladenine, a hormone from the cytokinin group, had a positive effect on the yielding of lettuce only in the spring season. By taking part in the division and growth of plant cells and stimulating photosynthesis, cytokinins influence the growth of plant biomass (Czerpak and Piotrowska 2003). In the studies conducted by Smoleń and Sady (2005), carrot yielded better when fertilised with benzyladenine, while foliar nutrition with benzyladenine combined with urea and molybdenum decreased its yields. In our experiment, the same combination had a positive effect on the weight of lettuce heads.

It is believed that cytokinins also contribute to the hydratation of plant cells (Czerpak and Piotrowska 2003), but in the present study no relationship between foliar nutrition and the moisture content of tissues has been found. The dry matter content was higher in plants grown under better light conditions, i.e. in a greenhouse covered with Gemme 4S film, and in plants cultivated in the spring season. The increase in dry matter levels under a higher insolation may have resulted from an increased intensity of transpiration caused by the light and temperature. The level of dry matter also depended on the form of nitrogen fertiliser. This is consistent with the results of Dapoigny et al. (2000), who found a medium containing solely the nitrate form of nitrogen to influence the hydration of plants due to an increased osmotic pressure of cells resulting from an increased concentration of nitrate ions in the vacuoles.

The nitrate content of the usable parts of vegetable plants constitutes an important indicator of the plant's biological value. Poorer light conditions decrease the activity of enzymes responsible for the metabolism of nitrates (Campbell 1999). In our studies, lettuce cultivated under worse light conditions (summer-autumn season) contained almost six times more nitrates than lettuce grown in spring. A similar effect of the season of cultivation on nitrate accumulation in greenhouse-grown lettuce was observed by Myczkowski et al. (1986). The results indicate that irrespective of the way of fertilisation, a considerably better quality of lettuce yields is achievable in the spring cultivation. Also higher nitrate levels in plants cultivated in the part of the greenhouse covered with a film with lower PAR transmittance (Ginegar) point to the marked influence of light on the accumulation of these compounds.

Foliar nutrition did not have any apparent impact on the nitrate contents of plants. The use of molybdenum, the co-factor of nitrate reductase, responsible for the activity of this enzyme (Campbell 1999), did not decrease the accumulation of nitrates in lettuce plants. The lack of response of plants to the foliar application of molybdenum may be due to the fact that the growing medium contained a sufficient amount of this element. Foliar nutrition with urea solution or solution of urea with molybdenum did not produce any beneficial effect, either. This is in contrast with Del Amor et al. (2007), who found foliar urea fertilisation to restrict nitrate accumulation. Other authors (Bednarz et al. 1998, Smoleń et al. 2006) observed no such effect or noted an increase in the nitrate content of plants receiving urea as a foliar fertiliser.

Many authors (Marschner 1995, Sady et al. 1995) reported significantly higher nitrate levels in plants fertilised with nitrate nitrogen compared to combined nitrate-ammonia fertilisation. In our studies, using a medium containing both forms of nitrogen (NO_3/NH_4) decreased the nitrate content of lettuce (by 48% in the spring cultivation, and by 32% in the summer-autumn season), when compared to nitrate form.

The ammonia nitrogen content of plants did not depend on whether the NH_4^+ cation was present in the growing medium or not. There were, however, differences due to the type of film covering the greenhouse. Plants cultivated in the part of greenhouse with better light conditions had a lower NH_4^+ content, which may indicate a more effective assimilation of nitrogen under a higher availability of PAR. In addition, higher levels of sugars in lettuce covered with Gemme 4S film might suggest that the higher intensity of radiation enhanced the efficiency of the metabolic processes in plants. However, the significantly smaller amount of protein nitrogen in plants grown under a film with a higher PAR transmittance provides evidence to the contrary.

Mozafar (1993) claims that nitrogen supplied to plants in the ammonia form decreases their vitamin C content compared to plants fed with nitrate nitrogen. In our studies, such was the case with the summer-autumn season, while the spring season showed a reversed pattern.

The type of greenhouse film had an impact on the levels of macronutrients in lettuce leaves. Plants grown in better light conditions (Gemme 4S film) contained smaller amounts of P and Mg in both seasons, as well as K in the spring season and Ca in the summer-autumn season. The more favourable light conditions contributed to heavier weights of lettuce. It is likely that the increase in the size of plants was accompanied by the effect of dilution of the components they had taken up.

Stratton et al. (2001) report that privet plants fed with nitrate nitrogen had higher K, Mg and Ca contents than plants supplied with ammonia nitrogen or fertilisers containing both forms. Since potassium, magnesium and calcium are taken up by plants in the form of cations, the presence of the ammonia cation in the medium may have an antagonistic effect on their uptake. In our studies, lettuce plants fertilised with a combination of the two nitrogen forms contained less Mg than those fertilised with nitrate nitrogen. By contrast, the Ca content, and the K content in the summer-autumn season, did not depend on the form of nitrogen fertiliser.

According to Yildirim et al. (2007), foliar nutrition with urea increases the levels of P, K, Mg and Ca in broccoli. This is at odds with our results indicating no effects of foliar fertilisation on the macronutrient contents of lettuce in either season of cultivation.

CONCLUSIONS

1. In both seasons, lettuce grown in a film greenhouse with a higher light transmittance (Gemme 4S film) produced higher yields that were of better quality as expressed by the nitrate, sugar, and dry matter contents of plants.
2. Fertilisation with a nitrate-ammonia solution resulted in decreased levels of nitrates and protein nitrogen in plants.
3. The effects of the type of film covering the greenhouse and the form of nitrogen fertiliser on the vitamin C content of plants depended on the season of cultivation.
4. P, K, Ca and Mg levels in plants depended on the type of film and form of nitrogen fertiliser. Plants growing under a film of lower light transmittance accumulated a larger amount of mineral constituents, except for Ca in the spring season and K in the summer-autumn season.
5. Foliar nutrition had no apparent effect on the yield and quality of lettuce, except for the spring season, when plants supplied with benzyladenine containing solutions produced heavier heads.

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WPŁYW RODZAJU FOLII POKRYWAJACEJ TUNEL, FORMY AZOTU NAWOZOWEGO ORAZ DOKARMIANIA DOLISTNEGO NA PLON I JAKOŚĆ SAŁATY

Streszczenie: W doświadczeniu badano wpływ rodzaju folii pokrywającej tunel, formy azotu nawozowego (100% N-NO_3 i 57% N-NO_3+43% N-NH_4) oraz dokarmiania dolistnego na plon oraz jakość sałaty uprawianej w sezonie wiosennym i letnio-jesiennym. Sałatę uprawiano na wełnie mineralnej, w tunelu foliowym podzielonym na dwie części pokryte folią różniącą się stopniem przepuszczalności promieniowania PAR. Rośliny 3-krotnie dokarmiano dolistnie roztworami zawierającymi: Mo lub benzyloadeninę lub mocznik i Mo lub mocznik i benzyloadeninę oraz roztworem zawierającym wszystkie trzy substancje, tj. mocznik, benzyloadeninę i Mo. W uzyskanym plonie oznaczano zawartość suchej masy, azotanów, formy amonowej azotu, azotu białkowego, cukrów rozpuszczalnych oraz P, K, Ca i Mg. W obydwu sezonach wegetacyjnych sałata uprawiana w tunelu pokrytym folią o większej przepuszczalności światła PAR zawiązywała główki o większej masie. Ponadto rośliny te charakteryzowały się istotnie niższą zawartością azotanów, NH_4^+, azotu ogólnego oraz P i Mg. Wpływ rodzaju folii pokrywającej tunel na zawartość witaminy C zależał od sezonu uprawy. Forma azotu nawozowego miała wpływ na zawartość suchej masy, wit. C, azotu białkowego, P i Mg oraz dodatkowo w sezonie letnio-jesiennym na masę główki sałaty. Większą masę wytworzyły rośliny uprawiane na pożywce azotanowej. Forma azotanowa wpłynęła na zgromadzenie przez rośliny istotnie większej ilości azotanów w porównaniu do roślin uprawianych na pożywce azotanowo-amonowej. W żadnym sezonie uprawy nie wykazano wpływu dokarmiania dolistnego roztworami soli na plon i jakość sałaty.

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