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Effect of differentiated nitrogen fertilisation on the yield and quality of leaf lettuce

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ABSTRACT

Two field experiments with leaf lettuce were conducted in 2006-2008. The first factor tested was the diversified contents of mineral nitrogen in the soil, amounting to 50, 100 and 150 mg N dm^{-3} before lettuce cultivation. The second factor tested four nitrogen fertilisers differing in chemical composition and in nitrogen form introduced into the soil: ammonium nitrate 34% N – (NH_4NO_3), calcium nitrate 15.5% N – ($Ca(NO_3)_2 \times H_2O + NH_4NO_3$), ammonium sulfate 20.0% N – ($(NH_4)_2SO_4$), and ENTEC 26% N – ($NH_4NO_3 + (NH_4)_2SO_4$ + 0.8% DNPP). Two cultivars of leaf lettuce were used: green leaf 'Casabella' (Lollo Bionda type) and red leaf 'Klausia' (Lollo Rosa type). The best source of nitrogen for 'Casabella' cultivar lettuce was ENTEC 26 fertiliser and calcium nitrate, which resulted in significantly higher yields as compared to ammonium sulfate, yet did not differ from the yields comprising plants fertilised with ammonium nitrate. In the case of the 'Klausia' cultivar, ENTEC 26 fertiliser and ammonium nitrate generated the best production results. Regardless the type of nitrogen fertiliser used, the increase in concentration of this element in soil from 50 mg N dm^{-3} to 150 mg N dm^{-3} resulted in a considerable increase in marketable yield of both cultivars with simultaneously higher nitrate accumulation and decreased dry matter in the 'Klausia' cultivar. Lettuce fertilised with ammonium sulfate as well as with ENTEC 26 presented significantly lower average nitrate content in leaves before harvesting than after application of ammonium and calcium nitrate as a source of nitrogen for the plants. Introduction of ammonium nitrate and calcium nitrate in the dose of 150 mg N dm^{-3} contributed to nitrate accumulation in the amounts exceeding permissible by legal regulations regarding the content of this element in lettuce, while application of ENTEC 26 allowed us to obtain a high yield size of both lettuce cultivars without risk of exceeding permissible nitrate content.

Key words: 'Casabella', 'Klausia', nitrogen dose, nitrogen source

INTRODUCTION

Similarly to other species of leafy vegetables, feathery leaf lettuce is characterised by a short growing period and a considerable tendency towards nitrate accumulation, which can result in decreased yield quality (Sady et al. 1995, Rożek 2000, Escobar-Gutierrez and Burns 2002). However, this disadvantageous phenomenon can be reduced by the application of practical fertilisation, taking into account the nutrition needs of the plants and the mineral nitrogen content in the soil. In leaf lettuce cultivation, the dose, type of nitrogen fertiliser, as well as the period and technique of its introduction all play an important role (Dapoigny et al. 2000, Kowalska et al. 2006). Due to the short growing period of this species, a standard practice is the application of the entire nitrogen dose at one time before transplants are planted. When reduced forms of nitrogen, i.e. ammonium sulfate or urea are used, nitrate content in lettuce leaves is usually lower than that obtained with fertilisation with

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nitrate form (Michałojć 2001, Wojciechowska 2004). Yet it should be noted that plant fertilisation with ammonium sulfate causes strong acidification of the soil and that this fertiliser features a high salt index, while lettuce is classified in the group of vegetables sensitive to salinity (Hähndel and Zerulla 2001, Sady 2006). The aim of the research was determination of the effect of nitrogen dose and form used in different types of nitrogen fertilisers on yielding and quality of two cultivars of leaf lettuce of the feathery type.

MATERIAL AND METHODS

Field experiments involving leaf lettuce were conducted in the years 2006-2008. They were established following a randomised split-plot method, in three replications, in a two-factorial system. The first factor (A) contained diversified contents of mineral nitrogen in the soil, amounting to 50, 100 and 150 mg N dm^{-3} before lettuce cultivation. The second factor (B) included four nitrogen fertilisers differing in chemical composition and in nitrogen form introduced into the soil: ammonium nitrate 34% N – (NH_4NO_3), calcium nitrate 15.5% N – ($Ca(NO_3)_2 \times H_2O + NH_4NO_3$), ammonium sulfate 20% N – ($(NH4)_2SO_4$), and ENTEC 26% N – ($NH_4NO_3 + (NH_4)_2SO_4$ + 0.8% DNPP). ENTEC 26 fertiliser contains a nitrification inhibitor, 3.4-dimethylopyrazophosphate, which blocks the activity of the *Nitrosomonas* bacteria species and stabilises the ammonium form of nitrogen (Linzmeier et al. 2001, Paschold et al. 2008). The concentration of mineral nitrogen in the control – fertilisation without nitrogen – ranged from 20 to 30 mg N dm^{-3}, while the remaining component concentrations met the requirements of lettuce nutrition.

Two cultivars of feathery leaf lettuce were cultivated in independent experiments: green leaf 'Casabella' (Lollo Bionda type) and red leaf 'Klausia' (Lollo Rosa type). The lettuce was grown from transplants produced in a greenhouse. In the second ten days of July lettuce seeds were sown into multipots filled with peat substrate of pH 6.20. The transplants were planted in 35 × 30 cm spacing in the third of August in 5 m^2 plots. Weed control was done mechanically and soil moisture was maintained at a level of 70% FWC. Lettuce harvesting took place in the third ten days of September. Healthy plants with rosette weight over 100 g were included in the marketable yield. Lettuce leaves were subjected to nitrate determination according to the potentiometric method. Dry matter was measured at 105°C to a constant weight (PN-90/A-75101/03). The results underwent statistical analysis using analysis of variance and the Tukey test, for significance level $\alpha = 0.05$.

RESULTS AND DISCUSSION

On the basis of the research, a significant effect of diversified nitrogen fertilisation on yield and quality of leaf lettuce was recorded. The average marketable yields for 'Casabella' (Tab. 1) fertilised with ENTEC 26 (21.12 t ha^{-1}) and calcium nitrate (21.00 t ha^{-1}) showed similar levels and were significantly higher than the yields obtained from plots where ammonium sulfate was applied (20.23 t ha^{-1}). The average marketable yields recorded after the use of ammonium nitrate did not significantly differ from the remaining tested fertilisers. This proves that the possibility of using different nitrogen forms exists in lettuce fertilisation. It partly confirms the results reported by Sady et al. (1990), who also did not notice any differences in lettuce growth and yielding when nitrate and reduced forms of nitrogen were introduced in hydroponic cultivation. Kowalska (1998) obtained similar results.

Regardless of the type of nitrogen fertiliser applied, the increase in the concentration of this component in the soil from 50 to 100 and 150 mg N dm^{-3} provided for a marked increase in the marketable yield of 'Casabella' cultivar lettuce from 18.82 to 21.08 and 22.44 t ha^{-1}. The use of calcium nitrate and ENTEC 26 fertiliser in a 150 mg N dm^{-3} concentration resulted in a significantly higher average marketable yield of that cultivar in comparison to that originating from plots fertilised with ammonium sulfate, and only slightly higher than the one from ammonium nitrate fertilised plots (Tab. 1).

According to the obtained results, the highest average marketable yield of 'Klausia' cultivar lettuce (19.04 t ha^{-1}) came from the plots fertilised with ENTEC 26 as a source of nitrogen (Tab. 2). The yield of lettuce fertilised with ammonium nitrate showed similar levels (18.66 t ha^{-1}), while markedly lower yielding was shown by plants fertilised with calcium nitrate (17.52 t ha^{-1}) and ammonium sulfate (17.58 t ha^{-1}). The latter ones did not show any significant differences regarding their average marketable yield.

As in the case of 'Casabella', it is possible to state that regardless of the nitrogen form, the increase in concentration of this element in soil from 50 mg to 100 and 150 mg N dm^{-3} brought about a considerable increase in the marketable yield of 'Klausia' leaf

Table 1. The effect of nitrogen fertilisation on marketable yield, dry matter and nitrate content of ‘Casabella’ feathery lettuce (mean for 2006-2008)

Type of fertiliser	Mineral nitrogen content in soil ($mg\ dm^{-3}$)			Mean
	50	100	150	
Marketable yield ($t\ ha^{-1}$)				
ENTEC 26	19.31	20.87	23.20	21.12
Calcium nitrate	20.36	19.37	23.26	21.00
Ammonium nitrate	18.12	21.69	22.50	20.77
Ammonium sulfate	17.49	22.40	20.79	20.23
Mean	18.82	21.08	22.44	20.95
Control				16.47
$LSD_{0.05}$ for: N dose - 0.61, type of fertiliser – 0.52, interaction I × II – 0.98				
Dry matter content (%)				
ENTEC 26	6.95	7.12	6.61	6.89
Calcium nitrate	6.62	6.60	6.50	6.57
Ammonium nitrate	7.05	7.26	6.96	7.09
Ammonium sulfate	6.85	6.24	6.41	6.50
Mean	6.86	6.80	6.62	6.76
Control				7.60
$LSD_{0.05}$ for: N dose – n.s., type of fertiliser – 0.41, interaction I × II – 1.08				
Nitrate content ($mg\ NO_3\ kg^{-1}$ f. m.)				
ENTEC 26	1758	2156	2436	2117
Calcium nitrate	1982	2388	3141	2504
Ammonium nitrate	1778	2321	2515	2205
Ammonium sulfate	1457	1852	2071	1793
Mean	1744	2179	2541	2150
Control				740
$LSD_{0.05}$ for: N dose – 116, type of fertiliser – 95, interaction I × II – 120				

lettuce – from 17.06 t ha^{-1} to 17.93 t ha^{-1} and 19.60 t ha^{-1}. Taking into account interactions, it can be noted that the highest marketable yield was obtained from plots where nitrogen content reached the level of 150 mg N dm^{-3} and its source was ENTEC 26 (20.53 t ha^{-1}) and calcium nitrate in the amount of (20.39 t ha^{-1}). In both lettuce cultivars the lowest marketable yields were recorded in the control treatments. The yield-forming role of nitrogen in the cultivation of lettuce and other vegetable crops has already been thoroughly verified by scientific research (Kozik and Ruprik 2000, Jarosz and Dzida 2006, Kalisz 2007). This information has been confirmed by our own study as well.

In view of the results obtained, ENTEC 26 fertiliser showed the highest fertilisation usability for both lettuce cultivars, providing the higher marketable yields. Hähndel and Zerulla (2001) reported comparable results, stating that the effects of ENTEC 26 and ammonium nitrate activity in this plant was similar, while the abovementioned fertiliser had an even more significant impact on the yields of such vegetables as cauliflower, radish, Chinese cabbage and lamb’s lettuce.

Increasing doses of nitrogen contributed to a diminishing average dry matter content in leaves of both lettuce cultivars, yet the differences were insignificant. Only in the ‘Klausia’ cultivar did elevated values of nitrogen concentration in soil from 50 to 100 mg N dm^{-3} result in a significant decrease in dry matter content in leaves. The ‘Casabella’ lettuce fertilised with ammonium nitrate contained markedly higher amounts of dry matter in its leaves than the plants fertilised with ammonium sulfate and calcium nitrate. A significantly higher content of dry matter in plants fertilised with ammonium nitrate and ENTEC 26 was recorded in ‘Klausia’ leaves as compared to those treated with calcium nitrate and ammonium sulfate. In the case of both lettuce cultivars, the highest content of dry matter was found in plants from the control treatment (Tabs 1 and 2). Similar results were recorded by

Table 2. The effect of nitrogen fertilisation on marketable yield, dry matter and nitrate content of 'Klausia' feathery lettuce (mean for 2006-2008)

Type of fertiliser	Mineral nitrogen content in soil (mg dm^{-3})			Mean
	50	100	150	
Marketable yield (t ha^{-1})				
ENTEC 26	17.44	19.17	20.53	19.04
Calcium nitrate	16.18	16.00	20.39	17.52
Ammonium nitrate	18.25	18.92	18.80	18.66
Ammonium sulfate	16.39	17.66	18.70	17.58
Mean	17.06	17.93	19.60	18.20
Control				14.75
$LSD_{0.05}$ for: N dose - 0.70, type of fertiliser - 0.58, interaction I × II – 1.08				
Dry matter content (%)				
ENTEC 26	7.95	7.98	7.55	7.83
Calcium nitrate	8.10	6.75	7.09	7.31
Ammonium nitrate	8.08	7.95	7.76	7.93
Ammonium sulfate	7.37	7.25	7.13	7.25
Mean	7.87	7.48	7.38	7.58
Control				8.25
$LSD_{0.05}$ for: N dose - 0.32, type of fertiliser - 0.41, interaction I × II - 0.54				
Nitrates content (mg NO_3 kg^{-1} f. m.)				
ENTEC 26	1790	2034	2223	2016
Calcium nitrate	1938	2179	2855	2324
Ammonium nitrate	1710	1691	3087	2163
Ammonium sulfate	1163	1900	2047	1703
Mean	1650	1951	2553	2051
Control				982
$LSD_{0.05}$ for: N dose – 98, type of fertiliser – 118, interaction I × II – 132				

Kowalska (1997), who wrote that lettuce cultivated in deficient nitrogen supply conditions featured hard leaves and increased amounts of dry matter. The accumulation of dry matter was also favoured by the application of ENTEC 26 fertiliser as a source of nitrogen and its lowest quantities were found in plants fertilised with ammonium sulfate, especially in soil contents ranging from 100-150 mg N dm^{-3}. Our observations concluded that the use of high doses of nitrogen did markedly affect nitrate accumulation in the leaves of the tested lettuce cultivars, and average nitrate content in 'Casabella' was higher (2150 mg NO_3 kg^{-1} f.m.) than that in 'Klausia' (2051 mg NO_3 kg^{-1} f.m.).

Plants grown in the control treatment and not fertilised with nitrogen (Tabs. 1 and 2) contained the smallest amounts of these compounds. Increased amounts of mineral nitrogen in soil, from 50 mg N dm^{-3} to 150 mg N dm^{-3}, contributed to a significant increase in average nitrate content, from 1744 mg NO_3 kg^{-1} to 2541 mg NO_3 kg^{-1} of the fresh matter of leaves in the 'Casabella' cultivar and, respectively, from 1650 mg NO_3 kg^{-1} to 2553 mg NO_3 kg^{-1} of the fresh matter of 'Klausia' lettuce. By analysing the effect of particular fertilisers on nitrate content, it is possible to state that the use of ammonium sulfate resulted in a considerable reduction in the average content of those compounds in leaves of both lettuce cultivars in comparison to the other fertilisers. The abovementioned results confirm numerous data found in the literature about the fact that fertilisation with reduced nitrogen forms evidently reduces nitrate concentration (Kowalska 1998, Wojciechowska 2004, Biesiada 2005, Jarosz and Dzida 2006, Kozik 2006, Wojciechowska and Siwek 2006). In the case of the remaining fertilisers, an advantageous influence of ENTEC 26 was reported on the reduced accumulation of nitrates, where average content in both examined cultivars was lower than after the use of ammonium nitrate and calcium nitrate. In 'Casabella' leaves, the introduction of ENTEC 26 resulted in a significant decrease in nitrate content as compared to calcium nitrate, while in 'Klausia', the same effect was present in comparison to ammonium nitrate and calcium nitrate. These results correspond with reports about the positive effects of fertilisers containing the DMPP nitrification inhibitor on vegetables' biological value, which was also pointed out in research by Händell and Zerulla (2001), Pasda et al. (2001), Kołota and Adamczewska-Sowińska (2007). Lettuce previously fertilised by an oxidised nitrogen form, i.e. calcium nitrate, was characterised by significantly higher nitrate content.

In conclusion, it is possible to state that the most advantageous production effects in the form of the highest yield were obtained when cultivating lettuce at an initial soil content of 150 mg N dm^{-3}. Yet the use of such quantities of nitrogen might lead to exceeding the permissible value of nitrates in leaves of both lettuce cultivars after the application of calcium, and after the introduction of ammonium nitrate in the 'Klausia' cultivar. When using high doses of nitrogen, special attention should be paid to nitrogen fertilisers, which means that one should choose fertilisers containing reduced forms of this component. The research results point to the conclusion that the application of ENTEC 26 resulted in very high marketable yields of both lettuce cultivars without any risk of exceeding permissible nitrate content.

CONCLUSIONS

1. The best sources of nitrogen for 'Casabella' lettuce were ENTEC 26 fertiliser and calcium nitrate, which, as compared to ammonium sulfate, enabled us to obtain significantly higher yields. In the case of 'Klausia' the best production results resulted from the use of ENTEC 26 fertiliser and ammonium nitrate.
2. Regardless the type of nitrogen fertiliser used, the increase in the concentration of this element in the soil resulted in a considerable increase in marketable yield of both cultivars with simultaneously higher nitrate accumulation and decreased dry matter in 'Klausia'.
3. Lettuce fertilised with ammonium sulfate as well as with ENTEC 26 was characterised by significantly lower average nitrate content in leaves than after the application of ammonium and calcium nitrate as a source of nitrogen for plants.
4. The application of ENTEC 26 resulted in a high yield size for both lettuce cultivars without the risk of exceeding permissible nitrate contents.

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WPŁYW ZRÓŻNICOWANEGO NAWOŻENIA AZOTEM NA PLONOWANIE I JAKOŚĆ SAŁATY LIŚCIOWEJ

Streszczenie: Badania polowe z sałatą liściową przeprowadzono w latach 2006-2008. Doświadczenia założono metodą losowanych podbloków w układzie dwuczynnikowym. Pierwszy czynnik stanowiły zróżnicowane zawartości azotu mineralnego w glebie, które przed rozpoczęciem uprawy sałaty wynosiły: 50, 100 i 150 mg N dm^{-3}. Czynnik drugi obejmował 4 nawozy azotowe różniące się formą azotu: saletra amonowa 34% N – (NH_4NO_3), saletra wapniowa 15,5% N – ($Ca(NO_3)_2 \times H_2O + NH_4NO_3$), siarczan amonu 20,0% N – ($(NH_4)_2SO_4$), ENTEC 26% N – ($NH_4NO_3 + (NH_4)_2SO_4$ + 0,8% DNPP). W niezależnych od siebie doświadczeniach uprawiano dwie odmiany sałaty liściowej typu pierzastego: o zielonych liściach – 'Casabella ' (typ Lollo Bionda) oraz o czerwonych liściach – 'Klausia' (typ Lollo Rosa).

Najlepszymi źródłami azotu dla sałaty odmiany 'Casabella' były nawozy ENTEC 26 i saletra wapniowa, które w porównaniu z siarczanem amonu zapewniły uzyskanie istotnie wyższych plonów, nie różniących się jednak istotnie od uzyskiwanych przy nawożeniu saletrą amonową. W przypadku odmiany 'Klausia' najlepsze wyniki produkcyjne zapewniło użycie nawozu ENTEC 26 i saletry amonowej. Niezależnie od rodzaju zastosowanego nawozu azotowego zwiększenie koncentracji tego składnika w glebie z 50 mg N dm^{-3} do 150 mg N dm^{-3} spowodowało istotny wzrost plonu handlowego obydwu odmian sałaty, przy jednoczesnym zwiększeniu bioakumulacji azotanów, oraz obniżenia zawartości suchej masy u odmiany 'Klausia'. Sałata nawożona siarczanem amonu, a także nawozem ENTEC 26 odznaczała się istotnie mniejszą średnią zawartością azotanów w liściach niż po użyciu saletry amonowej i wapniowej jako źródła azotu dla roślin. Zastosowanie saletry amonowej i wapniowej w dawce 150 mg N dm^{-3} przyczyniło się do nagromadzenia azotanów w ilościach przekraczających dopuszczalne ustawowo zawartości tego składnika w sałacie, natomiast użycie nawozu ENTEC 26 pozwoliło na uzyskanie wysokiego plonu obydwu odmian sałaty bez ryzyka przekroczenia dopuszczalnej zawartości azotanów.

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