EFFECT OF AGRONOMIC MANAGEMENT PRACTICES ON LETTUCE QUALITY

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Abstract

The effect of different agronomic strategies on the nutritional quality of head lettuce was investigated. The factors included were irrigation type, fertiliser input type and level. The assessed ingredient parameters were nitrate, lutein, ß-carotene and polyphenols. Hygiene was described by total aerobic bacterial count and number of coliform bacteria, *Escherichia coli*, *Salmonella enteritidis*, *Enterococcus* and *Enterobacteriaceae*. Lettuce treated with mineral nitrogen fertiliser (calcium ammonium nitrate) displayed a higher nitrate content than lettuce treated with organic manures (fresh farmyard manure (FYM), rotten FYM, fermented nettle extract). Nitrate concentration in lettuce tended to increase with increasing amounts of fertiliser, independent of fertiliser type. Fertiliser type and level also affected the carotenoid content. Rapidly available nitrogen from mineral fertiliser gave higher lutein levels compared with slowly released nitrogen. Similar results were observed for ß-carotene. There were no obvious differences regarding polyphenols for the different modes of fertiliser input. The bacteriological quality was only marginally or not at all influenced by the type of fertiliser.

Introduction

Public concern about food quality and safety is steadily increasing. The judgement of fresh vegetables depends on visual characteristics as well as on nutritional quality. The idea of nutritional quality includes beneficial and harmful ingredients, taste, fragrance, freshness and shelf-life (Köpke, 2005) as well as the risk of toxic pathogens (Sagoo *et al*., 2001). Regarding lettuce, the marketable and nutritional quality depends heavily on the agronomic strategy used. Fast release of nitrogen (N) from fertilisers or a surplus of N can lead to an increase in nitrate content of plant tissues (Vogtmann *et al*., 1984; Sørensen *et al*., 1996), synthesis of N-containing compounds and a decrease in beneficial phytochemicals (Brandt *et al*., 2001). Contamination with enteric bacteria has been postulated for lettuce and other vegetables (Doyle, 1990). Therefore, the aim of our study was to assess the effect of different fertiliser types and application levels on desirable and undesirable ingredients, including the risk of transfer of enteric bacteria from organic fertilisers by the splash effect of raindrops or overhead irrigation.

Methodology

Field experiments

Head lettuce was grown in a three-factorial field experiment with 4 replications in two different seasons during 2004. The field trials were located on the organic research farm 'Wiesengut' in North-Rhine Westphalia, Germany (50°48'N, 7°17'O). Treatments were fertiliser input types (fresh farmyard manure (FYM), composted FYM, fermented nettle extract (*Urtica dioica*), calcium ammonium nitrate (CAN) combined with fertiliser input levels of 85 kg N/ha and 170 kg N/ha, respectively. During the rainy summer 2004, no differentiation by the third factor irrigation (overhead vs. tap irrigation) was given, resulting in 8 replications for the fertiliser treatments. Fertilisers were incorporated into the soil using a mouldboard plough. The first trial was planted in May and the second in August. With the exception of mineral N-fertiliser application, the experiments were conducted according to the rules of Organic Agriculture. The plants were harvested at optimal maturity. The assessed parameters were nitrate, lutein, ß-carotene, polyphenols, level of total aerobic bacterial count (CFU: colony forming units), numbers of coliform bacteria, *E. coli*, *Enterobacteriaceae*, *Enterococcus* and *Salmonella enteritidis*.

Analysis

For nitrate and secondary metabolites analysis, lettuce heads were quick-frozen and shredded after removal of outer leaves. The nitrate content was determined by continuous-flow techniques, carotenoids were analysed by HPLC techniques, polyphenols by Folin-Ciocalteu assay. For microbiological investigations, lettuce heads were shredded under sterile conditions. A pooled sample was analysed using standard microbial detection and quantification assays. Results were statistically evaluated by ANOVA and Tukey test.

Results and brief discussion

Nitrate content was a function of fertiliser type and input level. In the spring trial, lettuce treated with mineral N-fertiliser had a higher nitrate content than the organically fertilised lettuce. This can be explained by the slower and continuous release of nitrogen from organic manures. Several studies confirmed that the nitrate content of organically grown vegetables is often lower than of vegetables treated with mineral-N fertiliser (Augustin *et al.*, 1977; Leclerc *et al.*, 1991). An increased level of all fertiliser types tended to result in a increased nitrate content. A conclusion about significances in the spring trial was not possible, because the data were not normally distributed. In the summer trial, lettuce treated with mineral-N fertiliser had a significantly higher nitrate content than organically fertilised lettuce. The increased level of mineral N-fertiliser resulted in a significantly higher nitrate content, while that of organic fertiliser (composted manure only) resulted in a significantly higher nitrate content. On the other hand, increased levels of fresh manure and nettle extract tended to lead to higher nitrate contents.

Fertiliser type and level also affected the lutein content (Table 1). In both trials, the application of fresh and composted manure resulted in significantly lower lutein contents than with fertilisers that release nitrogen more rapidly. Increased fertiliser levels caused significantly higher lutein contents. Fertiliser type and level also affected the ß-carotene content. The spring trial showed an interaction between fertiliser type and level. Low levels of fresh and composted manure resulted in a significantly lower ß-carotene content than the same levels of nettle extract and mineral N-fertiliser. An increased level of composted manure showed a significantly increased ß-carotene content, while a higher level of fresh manure, nettle extract and mineral fertiliser showed no effect. In the summer trial, no interactions between fertiliser type and level were determined. Lettuce treated with fresh and composted manure had a significantly lower ß-carotene content compared with lettuce treated with nettle extract and mineral N-fertiliser. An increased level of all fertiliser types resulted in a significant increase in ß-carotene content. The polyphenol content was not affected by fertiliser type and amount in the spring trial. In the summer trial, fresh and composted manure application resulted in significantly lower levels compared with mineral N-fertiliser. A higher fertiliser level did not affect the polyphenol content for all fertiliser types. While there were no differences between the seasons with respect to lutein content, significant interactions between the experimental factors and the seasons were assessed for fertiliser and season for the parameters ß-carotene and polyphenol. The polyphenol content of lettuce fertilised with organic fertilisers was lower in plants grown in late summer than in crops grown in late spring. An application of mineral N-fertiliser in the spring trial resulted in a lower polyphenol content than in the summer trial. Similar to the polyphenols, the ß-carotene content of lettuce fertilised with organic fertilisers was lower in summer-grown plants than in spring-grown plants. The ß-carotene content of lettuce fertilised with mineral N-fertiliser was not affected by the season. These findings suggest an environmental influence on the ß-carotene and polyphenol formation in lettuce treated with organic fertilisers. Seasonal differences in ß-carotene and lutein levels between winter- and summer-grown kale cultivars were also reported by Mercadante and Rodriguez-Amaya (1991).

Table 1: Lutein, ß-carotene and polyphenol content (µg per g fresh weight) of lettuce growing in late spring and late summer 2004.

	Lutein		ß-carotene		Polyphenols	
Treatment	Spring	Summer	Spring*	Summer	Spring	Summer
Fresh FYM	5.83 b	4.76 b	6.30 b*	3.68 c	80.75 a	75.76 b
Composted FYM	6.64 b	5.30 b	7.02 ab*	3.79 c	90.92 a	72.03 b
Nettle extract	8.16 a	7.49 a	8.04 a*	5.92 b	89.93 a	82.95 ab
CAN	7.95 a	8.88 a	7.83 a *	7.69 a	86.79 a	95.28 a
Fertiliser level 85 kg/ha	6.68 b	6.07 b	6.95 b*	4.76 b	84.42 a	80.35 a
Fertiliser level 170 kg/ha	7.60 a	7.15 a	7.64 a*	5.78 a	89.77 a	81.16 a

Significance of differences (α=0.05) between treatments within season (column) are denoted by different letters (Tukey test)
* significant interactions between fertiliser type and level

In the spring trial, no effect of fertiliser input type on bacteriological quality was observed. *Escherichia coli* and *Salmonella enteritidis* were not detected in any sample. When lettuce was fertilised with mineral N-fertiliser in the summer trial, total aerobic bacterial count and the level of coliform bacteria and *Enterobacteriaceae* were significantly lower compared with lettuce treated with organic manures. Independent of the type of fertiliser, *Escherichia coli* was only isolated in very low numbers (>10< 100 CFU/g). There were three positive *Escherichia coli* samples in lettuce treated with fresh FYM, one positive sample in lettuce fertilised with composted FYM, two samples in lettuce fertilised with fermented nettle extract, and four positive samples in lettuce treated with CAN. *Salmonella enteritidis* was not detected in any sample.

Table 2: Total aerobic bacterial count, coliform bacteria, *Enterobacteriaceae* and *Enterococcus*, *Salmonella* and *E. coli*, for lettuce growing in late spring and late summer 2004 (log_{10} colony forming units/g).

Enteric bacteria		**Fresh FYM**	**Composted FYM**	**Nettle extract**	**CAN**
Total aerobic bacterial count	Spring	6.76 a	6.24 a	6.33 a	6.35 a
	Summer	6.36 a	6.39 a	6.35 a	5.68 b
Coliform bacteria	Spring	5.78 a	6.07 a	5.40 a	5.89 a
	Summer	5.21 a	5.30 a	5.12 a	4.03 b
Enterobacteriaceae	Spring	6.20 a	6.08 a	5.63 a	6.01 a
	Summer	6.27 a	6.26 a	6.13 a	5.28 b
Enterococcus	Spring	2.82 a	2.67 a	2.85 a	3.08 a
	Summer	1.10 b	2.42 a	1.88 a	2.36 a
Salmonella	Spring	0*	0*	0*	0*
	Summer	0*	0*	0*	0*
E. coli	Spring	0*	0*	0*	0*
	Summer	3*	1*	2*	4*

Significance of differences (α=0.05) between treatments within season (lines) are denoted by different letters (Tukey-test)
*number of positive samples with >10<100 CFU/g (n=16)

The results of the spring trial are in agreement with results published by Johannessen *et al.* (2004), who did not detect any impact of fertiliser type on the bacterial quality of lettuce. These findings suggest that there is no negative effect of untreated manure on bacteriological quality. Differences observed in the summer season trial are probably due to the weather impact. Johannessen *et al.* (2004) explained variations between two trials through different temperatures and precipitation. The absence of *Salmonella enteritidis* in both trials is in agreement with studies of McMahon and Wilson (2001), who did not detect any Salmonella in organic vegetables.

Conclusion

The results confirm that readily available N from mineral fertiliser can increase the nitrate content of lettuce tissue. On the other hand, the level of anticarcinogenic carotenoids also tended to increase after mineral N-fertiliser application. The microbiological results suggest that fertiliser type does not, or only slightly, affect the hygienic quality of lettuce when manures are incorporated into the soil and not left on the soil surface or in the upper soil layer. Thus, an adequate agronomic practice of cultivating lettuce can ensure a high hygienic quality of the produce.

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