

Effects of different fertilization practices on the quality of stored carrot

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Abstract. The effects of different fertilization practices on quality constituents of stored carrots were studied. The field experiments were carried out in southern Finland, and the carrots were stored in refrigerated storage for six months in 1985 and four months in 1986. After storage period the marketable yield and weight loss were measured, carotene content was analyzed and a sensory evaluation for taste and texture was performed in both years. In 1986, also $\text{NO}_3\text{-N}$, N, P, K, Ca, Mg, ash, glucose, fructose and sucrose were analysed.

In 1985, after storage, NPK fertirrigations without basic fertilization showed a tendency to produce a lower marketable yield than single application and placement fertilization. In 1986, after storage, split application and NPK fertirrigations showed a tendency to produce a lower marketable yield than unirrigated single application. The supraoptimal N amount showed a tendency to have a higher carotene content than optimal N amount, and NPK fertirrigations lower $\text{NO}_3\text{-N}$ content than irrigated single application. The irrigated placement and broadcast treatments yielded high K contents. The unfertilized treatments yielded higher marketable yield, lower $\text{NO}_3\text{-N}$, N and K contents than fertilized treatments as an average.

Index words: carrot, broadcast fert., placement fert., fertirrigation, fertilizer application, quality, storage, organic cultivation

Introduction

The carrot (*Daucus carota* L.) is an important vegetable crop both for processing and for the fresh produce market. The storage period in Finland may be as long as six or seven months, from October to March or April. Carrots are harvested while in full metabolic activity. A well-defined stage of biochemical maturity has not been determined (NILSSON 1987), but the optimum harvest date

of carrots seems to be reached when the contents of carotene and sucrose are highest and the content of monosaccharides and the respiration intensity are lowest (FRITZ & HABBEN 1975). The aim of storage is to preserve the same properties as present in the carrot at the time of harvest; yet quantitative and qualitative losses do occur. In literature there is shortage of results of the effects of fertilization

Table 1. The fertilization treatments and the total amounts of nutrients and irrigation water.

Treatment	Number and time of fertilizer applications	Macronutrient amounts in 1986 ³ kg/ha			Irrigation water amounts in 1985 and 1986 mm
		N	P	K	
Unfertilized					
Unirrigated	0	0	0	0	0
Irrigation	0	0	0	0	3 × 10
NPK placement					
Unirrigated	1 before sowing	80	35	133	0
Irrigation	1 before sowing	80	35	133	3 × 10
NPK broadcast					
Unirrigated	1 before sowing	80	35	133	0
Irrigation	1 before sowing	80	35	133	3 × 10
NPK fertirrigations					
No basic	3 during season	80	29	160	3 × 10
Half the basic ¹	1 before sowing and 3 during season	80	32	142	3 × 10
PK placement ²					
3N-fertirrigations	1 before sowing and 3 during season	81	56	133	3 × 10
4N-fertirrigations	1 before sowing and 4 during season	155	56	133	4 × 10

¹ Half of the nutrients were given in basic placement fertilization and half in NPK fertirrigations.

² Phosphorus and potassium were given in basic placement fertilization and nitrogen in fertirrigations.

³ The nutrient amounts were 30 % higher in 1985 than in 1986.

amounts or practices on the quality of stored carrots.

The purpose of the present investigation is to study whether different fertilization practices during the growing period affect the quality of stored carrot.

Materials and methods

Carrot cv. Nantes Duke Notabene 370 Sv was cultivated on the Kotkaniemi experimental farm in southern Finland during the growing seasons of 1985 and 1986 (EVERS 1988). The field experiments were set up according to the method of completely randomized blocks, with four blocks and ten treatments (Table 1). In NPK placement and NPK broadcast treatments, all nutrients were given in single application. NPK fertirrigations and PK placement with N fertirrigations treatments were carried out as split application of NPK or N.

The carrots were sown on fine sand soil (15–30 % clay, 12–20 % humus), in the beginning of June. After a four-month growing period the carrots were harvested manually, and 8 kg (1985) and 15 kg (1986) samples, packed in wooden boxes, were stored in a refrigerated storage ($\pm 0.7^{\circ}\text{C}$, 90–95 % RH). In 1986, a bigger amount was stored, because more analyses were done and because the storage ability in 1985 was poor. On 2 April 1986, after six months of storage, and 23 February 1987, after four months of storage, the samples were weighed to find out the weight loss and thereafter the samples were graded. Because storage loss was so great in 1985, the storage period was in 1986 shorter. The grading was done roughly into two categories only (1) the marketable yield, which included grades I and II and (2) the remnants (broken, wilted and diseased carrots). In both years the carotene content was determined as described in EVERS (1989 a). In the used method $\alpha + \beta$ -

Table 2. The effect of different fertilization practices on the marketable yield and weight loss after storage.

Treatment	1985		1986		Average of years 1985 and 1986	
	Marketable yield ¹ %	Weight loss ² %	Marketable yield %	Weight loss %	Marketable yield %	Weight loss %
Unfertilized	21.5	26.2	69.1	14.0	45.3	20.1
Unfertilized and irrigated	36.8	28.9	63.0	15.0	49.9	22.0
Placement fertilized	39.6	23.9	63.1	17.0	51.4	20.5
Placement fertilized and irrigated	41.8	25.5	60.3	15.7	51.1	20.6
Broadcast fertilized	36.2	26.8	63.0	16.2	49.6	21.5
Broadcast fertilized and irrigated	39.2	27.7	54.2	18.0	46.7	22.9
NPK fertirrigations, no basic	22.2	31.0	58.3	16.7	40.3	23.9
NPK fertirrigations, half the basic	44.6	26.0	54.8	16.2	49.7	21.1
PK placement with 3N fertirrigations	46.6	25.4	55.8	15.2	51.2	20.3
PK placement with 4N fertirrigations	25.5	32.1	58.4	23.0	42.0	27.6
Mean	35.4	27.4	60.0	16.7	47.7	22.1
Organically cultivated carrots						
Location one			86.4	13.7		
Location two			86.0	14.0		

¹ Indicates how many per cents of the original sample weight was still marketable after storage period.

² Indicates how many per cent the 8 kg sample in 1985 and the 15 kg sample in 1986 had lost of its weight during storage period.

carotene was determined. The sensory evaluation of taste and texture was done as described in EVERS (1989 c). For carrots grown during the growing season of 1986, NO₃-N, N, P, K, Ca, Mg, ash, dietary fibre were analysed as described in EVERS (1989 b), glucose, fructose and sucrose were analysed as described in EVERS (1989 c). Carrot samples grown in 1985 were analysed only from two blocks, and carrot samples grown in 1986 from all four blocks were analysed; but for sensory evaluation carrots from all blocks were pooled, and one sample was evaluated for each treatment. The results were analysed statistically by contrast analysis (STEEL & TORRIE 1980). The differences between treatments were considered significant at $p \leq 0.05$, and were considered to show a tendency at $p \leq 0.1$.

In 1986, samples from two organically cultivated fields were collected for comparison. These carrots were grown from the same seed material, but the geographical position, climate and soil characteristics were different.

Organically cultivated carrots were stored in the same place as the carrots grown in the fertilization experiments. The organically cultivated samples were not compared statistically with those of the fertilization experiment.

Results

Marketable yield

In 1985, after a six-month storage period, the marketable yield was only 35 % (mean of all treatments) of the original amount put into storage at harvest. In 1986, after a four-month storage period, the marketable yield was 60 % of the original amount put into storage at harvest (Table 2).

In 1985, no statistical significantly differences in marketable yield after storage were detected between fertilization practices. Some tendencies were observed; placement fertilization, single application and irrigated single application resulted in a higher marketable yield

Table 3. Contrasts and the significances of differences (* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$) in marketable yield, weight loss, carotene, $\text{NO}_3\text{-N}$, N, P, K, ash and total sugars after storage in contrast analysis.¹

	1985					1986				
	Market-able yield	Weight loss	Carotene	$\text{NO}_3\text{-N}$	N	P	K	Ash	Total sugars	
Unfertilized										
Not irrigated										
Normal N										
Placement fert.										
Placement fert.										
Placement fert.										
Placement fert.										
Broadcast fert.										
Broadcast fert.										
Broadcast fert.										
Single application										
Single application										
Single application										
Irrigated single appl.										
Irrigated single appl.										
Irrigated single appl.										
Irrigated single appl.										
Unirrig. single appl.										
Unirrig. single appl.										
Unirrig. single appl.										
P & K placement										
PK placement with N										
PK placement with N										
	Market-able yield	Weight loss	Carotene	$\text{NO}_3\text{-N}$	N	P	K	Ash	Total sugars	
vs. fertilized	0.01*	0.06*		0.004**	<0.001***	0.1	<0.001***	0.006**	0.09	
vs. irrigated	0.007**		0.1				0.03*	0.1		
vs. big amount N										
vs. broadcast fert.										
vs. split application										
vs. NPK fertirrigation, no basic fert	0.1						0.06			
vs. NPK fertirrigations ²	0.08						0.06			
vs. PK placement with N fertirrig.										
vs. split application										
vs. NPK fertirrigation, no basic fert.							0.01*			
vs. NPK fertirrigations							0.05*			
vs. PK placement with N fertirrig.							0.01*			
vs. split application							0.04*			
vs. NPK fertirrigation, no basic fert.							0.007**			
vs. NPK fertirrigations							0.06			
vs. PK placement with N fertirrig.	0.07	0.1					0.01*			
vs. split application							0.04*			
vs. NPK fertirrigation, no basic fert.							<0.001***			
vs. NPK fertirrigations							0.004**			
vs. PK placement with N fertirrig.							<0.001***			
vs. split application							0.002**			
vs. NPK fertirrigation, no basic fert.										
vs. NPK fertirrigations										
vs. PK placement with N fertirrig.										
vs. split application										
vs. NPK fertirrigation, no basic fert.										
vs. NPK fertirrigations										
vs. PK placement with N fertirrig.										
vs. P & K not placement										
vs. NPK fertirrigation, no basic fert.										
vs. NPK fertirrigations										
	0.08			0.1						
	0.06									

¹ No significant differences were found in 1985 in carotene, taste and texture, and in 1986 in dry weight %, Ca, Mg, glucose, fructose, sucrose, taste and texture.

² This contrast includes NPK fertirrigations with and without basic fertilization.

³ The values $0.05 < p \leq 0.1$ were not regarded statistically significant, but was regarded to show a tendency.

after storage than did NPK-fertirrigations (Table 3).

In 1986, unfertilized and unirrigated treatments resulted in a higher marketable yield after storage than did fertilized treatments or irrigated treatments, respectively (Table 3). There was a tendency for unirrigated single application to produce a higher marketable yield after storage than did split application or NPK fertirrigations without or with basic fertilization.

Weight loss

In all treatments, weight loss averaged 27 % in 1985 and 17 % in 1986 (Table 2). In 1985, no statistically significant differences in weight loss were detected between fertilization practices, but placement fertilization, single application and unirrigated single application had a tendency to have lower weight loss than did NPK fertirrigations (Table 3). In 1986, no significant differences between fertilization practices were observed, but unfertilized treatments had a tendency to have lower weight loss than fertilized treatments (Table 3).

Organically cultivated carrots kept very well in storage. 86 % of the harvested sample was marketable after the storage period. Weight loss was similar to that of carrots grown in the fertilization experiment, but the amount of broken, wilted and infected carrots was much smaller (Table 2).

Dry matter content

The dry weight increased 1–8 % during the storage period, but there were no significant differences between fertilization practices (Table 4).

Carotene

At harvest, the carotene content was higher in 1986 than 1985 (EVERS 1989 a). After storage the carotene content was lower in 1986 than 1985 (Table 5). In 1985, the carotene content increased in storage in most of the treat-

ments, whereas in 1986 it decreased during storage (Table 4).

No statistically significant differences in carotene content after storage between fertilization practices were found. In 1986, there was a tendency for a supraoptimal amount of N treatment to have a higher carotene content after storage than did treatments with an optimal amount of N (Table 3). After storage, carrots cultivated organically at location one had a higher carotene content and those cultivated at location two had a carotene content similar to that of carrots grown in the fertilization experiment (Table 5).

Nitrate-nitrogen

After storage period the unfertilized treatments had significantly lower $\text{NO}_3\text{-N}$ content than the fertilized treatments (Table 3). There were no significant differences between fertilization practices, but NPK fertirrigations had a tendency to have lower $\text{NO}_3\text{-N}$ content than irrigated single application (Tables 3 and 5).

In organically cultivated carrots the $\text{NO}_3\text{-N}$ content was of the same magnitude as the lowest $\text{NO}_3\text{-N}$ content of carrots grown in the fertilization experiment (Table 5).

Macronutrients (N, P, K, Ca, Mg)

The macronutrient contents (N, P, K, Ca and Mg) had increased during the storage period in carrots grown in all the fertilized treatments. The increase was 10–14 % as an average for the treatments as can be calculated from results in Table 4. After storage, carrots in fertilized treatments had significantly higher N, P and K contents than did unfertilized treatments (Table 3). This was the only statistically significant difference observed in N and P contents. Many significant differences in K content were detected in many contrasts (Table 3), but all these are based on high K contents after storage in irrigated single applications eg. irrigated broadcast and irrigated placement fertilization (Table 5).

Table 4. The effects of different fertilization practices on the change (%) of quality from harvest to the end of storage period.

	Carotene		Taste scores		Texture scores		1986													
							Dry weight per cent		NO ₃ -N	N	P	K	Ca	Mg	Ash	Glucose	Fructose	Sucrose	Total**	Ratio mono-saccharides to sucrose
	1985	1986	1985	1986	1985	1986	1985	1986												
Unfertilized	-	-27	-27	-19	-30	-20	+4	+14	-3	+6	+5	+10	+4	+5	+52	+43	-14	+12	+71	
Unfertilized and irrigated	+62	-25	-20	-15	-32	-18	+5	-15	+21	+10	+14	+7	+8	-3	+56	+52	-16	+12	+71	
Placement fertilized	+4	-27	-10	-17	-27	-17	+7	+14	+12	+6	+5	+10	+4	-22	+58	+49	-19	+11	+86	
Placement fertilized and irrigated	+20	-19	-13	-29	-20	-20	+8	+8	+19	+8	+17	+17	+18	-18	+61	+53	-22	+9	+117	
Broadcast fertilized	+36	-35	-35	-22	-21	-18	+5	+24	+13	+13	+14	+13	+14	-21	+59	+56	-16	+11	+83	
Broadcast fertilized and irrigated	+38	-22	-33	-30	-24	-30	+6	+8	+25	+15	+19	+10	+12	-8	+49	+46	-12	+12	+71	
NPK fertirrigations, no basic	-16*	-22	-42	-20	-25	-24	+6	-9	+24	+19	+15	+10	+8	-5	+58	+49	-13	+12	+83	
NPK fertirrigations, half the basic	+21	-33	-19	-27	-17	-25	+6	-18	+19	+11	+3	+17	+20	-3	+98	+79	-28	+13	+180	
PK placement with 3N fertirrigations	-2	-31	-21	-33	-26	-20	+1	+20	+3	+16	+13	+7	±0	+3	+54	+48	-10	+16	+50	
PK placement with 4N fertirrigations	-2	-17	-29	-19	-35	-24	+8	+23	+9	+10	+7	+10	+10	+1	+74	+65	-5	+22	+67	
Organically cultivated, location one	-16		+3		-16		+1	-13	-5	+7	+14	+8	+15	±0	+71	+69	-33	+8	+143	
Organically cultivated, location two	-26		+16		-7		+6	+23	-5	-1	+8	+4	+5	-13	+92	+102	-50	+10	+286	

* Carrots were wilted, not in marketable condition.

** Calculated value, sum of glucose, fructose and sucrose.

Table 5. The effect of different fertilization practices on the carrot quality determined after storage.

	Carotene mg/100 g FW		Scores				1986										Ratio mono- saccha- rides to sucrose		
	1985	1986	Taste		Texture		Dry weight %	% in dry matter					% in fresh weight						
			1985	1986	1985	1986		NO ₃ -N	N	P	K	Ca	Mg	Ash	Glu- cose	Fruc- tose		Su- crose	Total**
Unfertilized	—	4.3	5.5	6.5	5.3	6.5	11.2	0.12	0.91	0.24	2.9	0.33	0.11	6.6	2.4	2.0	3.6	7.9	1.2
Unfertilized and irrigated	5.5	4.3	6.1	6.5	5.3	6.4	11.3	0.12	0.94	0.23	2.9	0.31	0.11	6.8	2.3	2.0	3.6	7.9	1.2
Placement fertilized	5.2	4.6	6.3	6.1	5.7	6.3	11.2	0.13	1.29	0.26	3.3	0.33	0.11	7.1	2.4	2.0	3.3	7.7	1.3
Placement fertilized and irrigated	5.0	4.6	6.4	5.5	6.2	6.1	11.1	0.16	1.21	0.25	3.8	0.34	0.11	7.4	2.2	1.9	3.2	7.3	1.3
Broadcast fertilized	5.4	4.3	5.0	6.5	6.1	6.7	11.2	0.16	1.34	0.25	3.5	0.34	0.12	7.2	2.0	1.8	3.5	7.4	1.1
Broadcast fertilized and irrigated	5.2	4.8	5.4	5.7	5.9	6.0	10.9	0.15	1.32	0.25	3.7	0.33	0.11	7.2	2.2	1.9	3.5	7.5	1.2
NPK fertirrigations, no basic	3.1*	4.6	4.7	6.7	5.9	6.6	11.0	0.14	1.28	0.23	3.3	0.32	0.11	7.3	2.1	1.7	3.6	7.3	1.1
NPK fertirrigations, half the basic	5.7	4.2	5.6	5.9	6.3	6.2	11.1	0.13	1.14	0.25	3.3	0.35	0.11	7.1	2.4	2.0	3.2	7.6	1.4
PK placement with 3N fertirrigations	5.2	4.4	5.3	5.6	5.7	6.6	10.9	0.14	1.23	0.27	3.3	0.32	0.11	7.6	2.3	1.9	3.4	7.6	1.2
PK placement with 4N fertirrigations	4.9	5.0	5.1	6.6	5.1	6.2	11.4	0.15	1.35	0.25	3.4	0.32	0.11	7.5	2.1	1.8	4.0	7.9	1.0
Organically cultivated, location one	5.9			7.1		7.2	10.6	0.12	0.86	0.28	2.8	0.25	0.13	7.0	2.6	2.1	2.8	7.6	1.7
Organically cultivated, location two	4.6			8.1		7.6	10.2	0.13	0.95	0.33	3.3	0.29	0.14	7.4	2.9	2.4	2.0	7.3	2.7

* Carrots were wilted, not marketable condition.

** Calculated value, sum of glucose, fructose and sucrose.

In organically cultivated carrots, the N and Ca contents were lower, the P and Mg contents were higher, and the K contents were similar to that of carrots grown in the fertilization experiments (Table 5).

Ash

During storage the ash content decreased in carrots cultivated in most of the treatments, but in carrots grown in unfertilized and in PK placement with N fertirrigations there was a slight increase (Table 4). No statistically significant differences between fertilization practices could be observed, but after storage the ash content was higher in carrots grown in fertilized treatments as compared to unfertilized treatments (Table 3). In irrigated treatments the ash content showed a tendency to be higher after storage as compared to unirrigated treatments (Table 3). After storage the ash content of the organically cultivated carrots was similar to that of carrots grown in fertilized treatments in the fertilization experiment (Table 5).

Sugars

The glucose and fructose contents increased and the sucrose content decreased during the storage period (Table 4). The calculated total sugar content (glucose + fructose + sucrose) increased and the ratio of monosaccharides to sucrose increased during the storage period (Table 4).

No significant differences between treatments could be found as to the glucose, fructose, sucrose and total sugar contents of carrots. The total sugar content in carrots grown in unfertilized treatments had a tendency to be higher than in carrots grown in fertilized treatments (Table 3).

In organically cultivated carrots, the glucose content was higher than that of carrots grown in the fertilization experiment (Table 5). The fructose content was high at location two. The sucrose content was lower than in the fertilization experiment. Thus the ratio of monosac-

charides to disaccharides was higher in organically cultivated carrots. The total sugar content was similar between the carrots grown in the fertilization experiment and the organically cultivated carrots (Table 5).

Taste and texture

The fertilization practices had no effect on taste or texture evaluated after storage, but the taste and texture scores were lower after the storage period than after harvest (Table 4). The organically cultivated carrots were an exception; their taste was poor at harvest (EVERS 1989 c), but after the storage period they received the best taste scores (Table 5).

Discussion

Marketable yield

In the present study the marketable yield of stored carrots was especially low in 1985, as the mean of treatments being 35 %. In Finland the average amount of marketable yield after 5–6 months storage is about 70 % (MUKULA 1957). In 1986, in the present study, the marketable yield after 4 months storage averaged 60 % and was thus slightly lower than the average. The main reason for the poor storage ability was heavy infection by *Mycocentrospora acerina* (R. Hartig) Deighton, know also by synonym *Centrospora acerina*, a soilborne disease (FJELDDALEN & RAMSFJELL 1969). In 1985, the storage period was longer than in 1986, thus the infection destroyed more carrots. Also weather conditions may have contributed to the particularly poor result in 1985. MUKULA (1957) demonstrates that varying climatic conditions in the growing districts affect the ability to keep, so that carrots grown in northern Finland incur greater losses in storage than carrots grown in central Finland, and in turn, carrots grown in the latter region have greater losses than those grown in southern Finland. In the present study, the mean day temperature and the number of sunshine hours in June and July

in 1985 were lower than in 1986, and lower than the long-term averages (EVERS 1988).

The average marketable yield after six months of storage in the study of NILSSON (1979) is 66 %, and the type (organic vs. inorganic) or amount of fertilizer applied have no effect on it during refrigerated storage. In the present study, too, no statistically significant differences in marketable yield after storage could be found between fertilization practices. However, split application or NPK fertirrigations showed a tendency to lower the marketable yield after storage. In 1986, the reason for this may be the water given with split or NPK fertirrigations treatments, because in 1986 the irrigation decreased significantly the marketable yield, and the split application and the NPK fertirrigation treatments had negative effects especially as compared to unirrigated single applications. In 1985, the NPK fertirrigations without basic fertilization decreased the marketable yield after storage as compared to placement fertilization, single application and irrigated single application, and thus water cannot be the reason for impaired storage ability in 1985. It would be interesting to study this subject further to confirm this observation and to find out the possible mechanism of action.

DRAGLAND (1978) reports that the time of irrigation does not affect the storage ability, but that an early drought period results in high root yield and good storage ability. He also reports that the nitrogen amount does not cause any statistically significant differences in storage ability, but an increasing amount of nitrogen shows a tendency to improve storage ability. In the present study, no such improvement could be detected. The treatment PK placement with 4N fertirrigations did get a supraoptimal N amount, but it showed rather worse than better keeping ability than did treatment with an optimal N amount (Table 2).

Weight loss

The weight loss was not affected by the fertilization practices in the present study. Also

in NILSSON's (1979) study the type of fertilizer (organic vs. inorganic) or amount of fertilizer applied had no effect on weight loss. In his study the mean weight loss (including trimming loss) is 22 %. FRITZ et al. (1979) reports a very close relation of storage losses and weather conditions of the last two weeks before harvesting. The sum of the rainfall as well as the average relative humidity are important determining variables, and the researchers hypothesizes that weight losses of vegetables are the lower the more turgid the plants were at harvest.

Dry matter

In the present study, the dry matter content increased slightly during storage, which indicates that the weight loss through water transpiration has been greater than the weight loss through dry matter consumption in respiration. The different fertilization practices did not effect the dry weight during storage. Nor do the type or the amount of fertilizer affect the dry matter content of stored carrots (NILSSON 1979).

Carotene

The supraoptimal N amount did not affect the carotene content in carrots at harvest (EVERS 1989 a) contrary to FREEMAN & HARRIS (1951) and HABBEN (1972), who have found that increasing the amounts of nitrogen also increases the carotene content. However, after storage in the present study in 1986, the supraoptimal amount of N in treatment PK placement with 4N fertirrigations had a tendency to have higher carotene content as compared to other treatments, where the N amount applied was though to be optimal on the basis of the yield. The decrease of carotene in the treatment PK placement with 4N fertirrigations was the smallest of all treatments (Table 4).

Carotene changed differently in the two years; for it increased in many treatments in 1985 and decreased in 1986 during storage.

Also the literature contains reports of contradictory results. BARNES (1936) has found that the carotene content decreases during storage; FRITZ et al. (1978) have found that the carotene content increases during storage, and they explain the increase as a concentrating effect occurring because the amount of dry matter decreases by respiration during storage. NILSSON (1979) does not find any significant differences in carotene content during storage in carrots grown with organic vs. inorganic fertilizers and with two fertilizer levels applied.

The carotene is determined from fresh carrots and the results are expressed in mg/100 g fresh weight. Thus the increase in carotene content could be explained not only by the concentrating effect mentioned by FRITZ et al. (1978), but also by loss of water through transpiration. In addition, LEE (1986) reports that biosynthesis of carotenes occurs in carrots during storage, and in his study the content of α - and β -carotene increases slowly for up to 100–125 days in storage and then decreases. The decrease in carotene content observed in the present study in 1986 may be the result of further biosynthesis or decomposition of the compound. Because carrots are an important vegetable consumed in Finland also in winter, it would be very important to study further the reasons for carotene changes in storage and the factors influencing it.

NO₃-N and macronutrients

The NO₃-N and macronutrient contents increased in most of the treatments and this trend is probably due to the water loss and the loss of dry matter respiration. As to NO₃-N, the treatments NPK fertirrigations without or with basic fertilization made an exception. Their NO₃-N contents had decreased during storage. These treatments had the highest NO₃-N contents at harvest (EVERS 1989 b) and probably, for some reason, the change from NO₃-N to amino-nitrogen was delayed in these treatments. They showed even a tendency to have lower NO₃-N content after storage than irrigated single application.

Ash

The decrease in ash content in most of the treatments was unexpected, while all the determined minerals increased during storage. This result should be verified in future studies.

Sugars

Glucose and fructose contents increased during storage in all treatments. This is in agreement with literature (BARNES 1936, SALMINEN et al. 1970, NILSSON 1979). Sucrose content decreased during storage in all treatments. Also in the study of NILSSON (1979) the sucrose content decreased during storage. The magnitude of changes in glucose, fructose and sucrose were similar in the present study and in the study of NILSSON (1979). In the studies of BARNES (1936) and SALMINEN et al. (1970) the sucrose content increased during the first months of storage and then decreased approximately to the level determined at harvest. In the present study, the ratio between monosaccharides to sucrose, and the total sugar content increased during storage. In the present study and in the study of NILSSON (1979) the increase of monosaccharides was greater than the simultaneous decrease of sucrose, and NILSSON (1979) hypothesizes that polysaccharides have been hydrolysed during storage. He also reports that the type or amount of fertilizer do not affect carrot sugar contents after storage. In the present study, the fertilization practices had no effect on the changes of glucose, fructose and sucrose during storage. The total sugar content had a tendency to be higher in unfertilized treatments than in fertilized treatments as an average. The situation was similar already at harvest (EVERS 1989 c). In unfertilized treatments the lack of nutrients probably have restricted the phytomass production and thus more photosynthates were left to be translocated into the storage cells.

Taste and texture

The indicative results of sensory evaluation at harvest indicates that NPK fertirrigations

have a positive effect and the placement of NPK fertilizer has a negative effect on taste and texture (EVERS 1989 c). After storage these trends could not be shown anymore, and fertilization had no effect on taste and texture. Carrot aroma is very complex and many compounds influence it (SIMON 1985). Possibly, during storage, the amounts or proportions of one or several of those compounds have changed, because the metabolic activity can be minimized but not stopped by lowering the temperature in refrigerated storage.

Organically cultivated carrots

Organically cultivated carrots were not in-

fluenced by the soilborne *Mycocentrospora acerina* (R. Hartig) Deighton, and thus their marketable yield after storage was considerably higher than that in the fertilization experiment. After storage, the contents of P, Mg, glucose, fructose, and carotene at location one as well as the taste and texture scores were higher in organically cultivated carrots than in carrots grown in fertilization experiment. On the other hand, the dry matter, N and K contents at location one as well as Ca and sucrose were lower in organically cultivated carrots than in carrots fertilized conventionally. The NO₃-N contents in organically cultivated carrots were similar to the lowest values in the fertilization experiment.

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Lannoitusmenetelmien vaikutus varastoidun porkkanan laatuun

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Eri lannoitusmenetelmien vaikutusta porkkanan 'Nantes Duke Notabene 370 Sv' varastoinnin jälkeiseen laatuun tutkittiin vuosina 1985 ja 1986. Kenttäkokeissa Kotkaniemen koetilalla Vihdissä oli vertailtavina lannoitusmenetelminä sijoitus- ja pintalannoitus (ilman kastelua ja kastelun kera), NPK-kastelulannoitus ja NPK-kastelulannoitus, jossa puolet ravinteista annettiin sijoittaen keväällä, sekä koejäsenet, joissa P ja K annettiin sijoittaen keväällä ja N (kaksi tasoa) kastelulannoituksena kasvukaudella. Kokeessa verrattiin myös ravinteiden kerta-levitystä jaksotettuun ravinteiden antoon. Neljän kuukauden kasvuaajan jälkeen käsin tehdyn sadonkorjuun yhteydessä 8 kg:n (1985) ja 15 kg:n (1986) näytteet vietiin koneellisesti jäädytettävään varastoon ($\pm 0.7^\circ\text{C}$, 90–95 % RH). Varastointiaika oli 6 kk vuonna 1985 ja 4 kk vuonna 1986. Varastoinnin jälkeen näytteistä punnittiin painohäviö ja kauppakelpoinen sato (I ja II luokat yhteensä), määritettiin karoteenipitoisuus ja aistinvaraisella arvioinnilla arvosteltiin maku ja rakenne. Vuonna 1986 määritettiin myös $\text{NO}_3\text{-N}$, N, P, K, Ca, Mg, tuhka, glukoosi, fruktoosi ja sakkaroosi. Tulokset analysoitiin kontrastianalyysillä.

Vuonna 1985 NPK-kastelulannoitusta saaneiden porkkanoiden varastoinnin jälkeinen kauppakelpoinen sato oli suuntaa-antavasti ($p \leq 0.1$) alhaisempi kuin koejäsenissä, jotka saivat ravinteita vain yhden kerran kasvukauden alussa, ja alhaisempi kuin sijoituslannoituksen saaneissa koejäsenissä. Vuonna 1986 varastoinnin jälkeinen kauppakelpoinen sato oli alhaisempi koejäsenissä, jotka saivat ravinteet jaksottain, ja koejäsenissä, jotka saivat NPK-kastelulannoitusta, kuin koejäsenessä, jossa ravinteet annettiin kerran keväällä eikä kasvukaudella kasteltu. Yli-suuren typpimäärän saaneen koejäsenen karoteenipitoisuus oli varastoinnin jälkeen korkeampi kuin sadontuotokyvyn perusteella optimaalisen typpimäärän saaneilla koejäsenillä, ja NPK-kastelulannoitusta saaneiden koejäsenten $\text{NO}_3\text{-N}$ -pitoisuus oli alhaisempi kuin koejäsenten, jotka saivat kastelua ja kaikki ravinteet kerralla keväällä. Sijoitus- ja pintalannoituksen kastelun kera saaneiden koejäsenten K-pitoisuudet olivat korkeat varastoinnin jälkeen. Lannoittamattomien koejäsenten kauppakelpoinen sato oli korkeampi ja $\text{NO}_3\text{-N}$ -, N- ja K-pitoisuudet matalammat kuin lannoitettujen koejäsenten vastaavat pitoisuudet.