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Effects of different fertilization practices on the NO_3-N, N, P, K, Ca, Mg, ash and dietary fibre contents of carrot

AINO-MAIJA EVERS

Kemira Oy, Espoo Research Centre, Luoteisrinne 2
SF-02270 Espoo, Finland

Abstract. The effects of different fertilization practices on the NO_3-N, N, P, K, Ca, Mg, ash and dietary fibre contents of carrots were studied in field experiments in southern Finland. Unirrigated and irrigated placement and broadcast fertilization, NPK fertirrigations without basic fertilization, NPK fertirrigations with NPK basic fertilization and PK placement with N fertirrigations were compared. Further, single application was compared with split applications. The results of 1986 were analysed by contrast analysis.

Fertilization practices affected the NO_3-N content in carrot, and irrigation increased the NO_3-N content. Highest NO_3-N contents were observed with NPK fertirrigations treatments. Fertilization increased the N content of roots, and nitrogen content was higher with PK placement with N fertirrigations as compared to NPK fertirrigations without basic fertilization, or to NPK fertirrigations. Placement fertilization increased P content as compared to broadcast fertilization, NPK fertirrigations without basic fertilization, NPK fertirrigations or split application. Irrigation decreased P content.

Fertilization increased the K contents of carrot roots as compared to unfertilized treatments, but there were no significant differences between fertilization practices. Fertilization had no effect on the Ca or Mg contents of carrot roots. Fertilization increased the ash content. Placement fertilization, single application and unirrigated single application yielded higher ash contents than did split application, NPK fertirrigations or PK placement with N fertirrigations. Fertilization and irrigation increased the dietary fibre content as compared to unfertilized and unirrigated treatments, respectively. Irrigated single application increased dietary fibre content as compared to split application and PK placement with N fertirrigations. Besides the fertilization experiment, samples from two organically cultivated fields were collected in order to obtain data concerning organically cultivated carrots.

Index words: fertilization practices, carrot, quality, nutrients, nitrate, ash, dietary fibre, organic culture

Introduction

The aim of modern vegetable cultivation is an even and high-quality yield. At harvest each plant should be similar in size and at the same developmental stage. Thus all cultivation practices should promote even germination, sprouting and growth.

The most common fertilization practice in vegetable cultivation is broadcast fertilization. With the present distribution methods, however, it is difficult to accomplish an even distribution, quaranteeing that every single plant gets the same amounts of nutrients at each growing stage. Fertilizer efficiency, too, can be intensified by developing even distribution systems and by dividing fertilizer applications according to the growth process of the plant being cultivated. Fertilizer placement has been shown in cereals to increase the uptake of nitrogen, in particular, but also the uptake of phosphorus and potassium (AURA 1967, KAILA & ELONEN 1970). Fertilizer placement increases the yield of barley and spring wheat, particularly at low fertilizer levels, but it has not increased the mineral content of grains (ESALA & LARPES 1986 a, b).

Only a few reports have been published concerning fertilizer placement in the cultivation of carrots. EKEBERG (1986) reported that fertilizer placement increased carrot yield, but decreased the dry matter content of carrots on peaty soil. The mineral contents of carrots were not determined in his experiment. CELIUS (1970) stated that the placement of phosphorus could be a profitable alternative in carrot growing. Carrot has a great need for phosphorus in the beginning of the growing season (BALVOLL 1978). On the contrary, as the germinating carrot seeds are sensitive to a high salt concentration in the soil (BALVOLL 1978), one could expect the placement of phosphorus and other nutrients below and beside the seed row to be beneficial.

In Holland, BAKER et al. (1984) compared broadcast fertilization with fertirrigation on lettuce. They found that the yield was very even with fertirrigation, but that the nitrate content was higher than with broadcast fertilization. High levels of nitrate in vegetables are undesirable, because NO_2 may be harmful to human health (CORRÉ & BREIMER 1979).

The objective of this study was to determine how placement and broadcast fertilization, fertirrigation and their combinations affect the nitrate, nitrogen, phosphorus, potassium, calcium, magnesium, ash and dietary fibre contents of carrots. Simultaneously with the field experiments in 1986, material from two organically cultivated fields were collected in order to get some data of the mineral, ash and dietary fibre contents of organically cultivated carrots.

Materials and methods

The field experiments were carried out on the Kotkaniemi Experimental Farm of Kemira Oy. in Vihti during the growing seasons of 1985 and 1986. Carrot cv. Nantes Duke Notabene 370 Sv was grown as reported elsewhere (EVERS 1988). The trials were set up according to the method of completely randomized blocks, four blocks and ten treatments (Table 1). Each plot was 25 m^2. The sample size was in 1985 20 carrots per treatment, in 1986 80 carrots per treatment for NO_3-N and 20 carrots per treatment for minerals, ash and dietary fibre. The blocks were determined separately.

In 1985, some preliminary carrot root and shoot samples for the NO_3-N, N, P, K, Ca and Mg determinations were collected three times during the growing season (1. = August 20, 1985, 75 days from sowing; 2. = September 10, 1985, 96 days from sowing; 3. = September 30, 1985, 116 days from sowing at harvest). Figure 2 was compiled according to the results of these sample determinations, and shows the development of macronutrient contents in carrot shoots and roots. The results of 1985 were not studied statistically.

In 1986, carrot root and shoot samples for the N, P, K, Ca, Mg, ash and dietary fibre determinations were collected at harvest, for the NO_3-N determinations three times during the growing period (1. = August 12, 1986, 66 days from sowing; 2. = September 3, 1986, 88 days from sowing; 3. = October 6, 1986, 121 days from sowing at harvest). The dietary fibre determinations were made only from roots. The results of 1986 were studied statisti-

Table 1. The fertilization treatments.

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	
No	fertilization					
	No irrigation	0	0	0	0	0
	Irrigation	0	0	0	0	3×10
NPK	placement					
	No irrigation	1 before sowing	80	35	133	0
	Irrigation	1 before sowing	80	35	133	3×10
NPK	broadcast					
	No irrigation	1 before sowing	80	35	133	0
	Irrigation	1 before sowing	80	35	133	3×10
NPK	fertirrigations					
	Without basic fertilization	3 during season	80	29	160	3×10
	Half the basic NPK fertilization[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 by basic placement fertilization and half by NPK fertirrigations.
[2] Phosphorus and potassium were given by basic placement fertilization and nitrogen in fertirrigations.
[3] The nutrient amounts were 30 % higher in 1985 than in 1986.

cally by contrast analysis (Steel & Torrie 1980).

The plant analyses were done by Viljavuuspalvelu Oy, Helsinki, a commercial laboratory. For the NO_3-N determinations the samples were ground, extracted in water and NO_3-N was determined by ion chromatography (IC) according to Hunt & Seymour (1985). Total N was determined according to the Kjeldahl method (Anon. 1984). For the P, K, Ca and Mg determinations the dried samples were ashed, extracted in HCl, and determined by plasmaemissiospectrometry (ICP-AES) (Anon. 1984). The dietary fibre determination was done according to the method described by Prosky et al. (1985). In Results, Figure 2, representing macronutrient contents during the season, is based on determinations in 1985, and the effects of different fertilization practices discussed in the text are based on determinations and statistical analyses made in 1986.

Results and discussion

Nitrate-N

Nitrate-N is undesirable in vegetables, because NO_2 is dangerous to health, especially in babies (Maynard et al. 1976, Corré & Breimer 1979). Nitrate-N accumulation in plants is attributed mainly to genotype, light intensity, day length, temperature, soil moisture content and nitrogen fertilization. Wide fluctuation has been observed also during a 24-hour period (Maynard et al. 1976, Corré & Breimer 1979). Carrot is not typically a species that concentrates NO_3-N, but as the consumption of carrots is considerable, the NO_3-N concentration in carrots is interesting.

According to the literature, in fertilizer experiments the NO_3-N contents have increased markedly with increasing amounts of nitrogen fertilization. Lehtinen (1984) reported an NO_3-N content in carrot roots of 2.08—3.53 g/kg dry matter (DM) (level of fertilizer N

Table 2. The effect of different fertilization practices on the NO_3-N, N, P, K, Ca and Mg contents of carrot roots and shoots at harvest in 1985 and 1986.

Treatment	% in dry matter											
	NO_3-N		N		P		K		Ca		Mg	
	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots	Roots	Shoots
1985												
Unfertilized	0.01	0.02	0.88	2.25	0.20	0.23	2.90	5.47	0.23	1.61	0.10	0.28
Placement fertilized	0.01	0.01	0.85	1.84	0.19	0.21	2.79	5.65	0.22	1.39	0.10	0.26
Broadcast fertilized	0.03	0.05	1.00	2.16	0.22	0.19	3.13	5.25	0.23	1.38	0.11	0.22
NPK fertirrigations, no basic fertilization	0.04	0.23	1.18	2.56	0.23	0.21	2.93	6.37	0.21	1.64	0.10	0.30
NPK fertirrigations, half the basic fertilization	0.01	0.04	0.91	1.99	0.22	0.19	3.15	5.25	0.24	1.42	0.10	0.24
PK placement with 3N fertirrigations	0.03	0.03	1.00	2.55	0.22	0.20	3.16	6.30	0.23	1.57	0.09	0.26
PK placement with 4N fertirrigations	0.03	0.04	1.06	2.16	0.22	0.19	3.45	6.05	0.21	1.35	0.12	0.30
1986												
Unfertilized	0.10	0.14	0.94	1.62	0.22	0.17	2.71	4.07	0.30	1.90	0.10	0.26
Unfertilized and irrigated	0.14	0.13	0.78	1.56	0.21	0.18	2.52	3.77	0.29	2.17	0.10	0.27
Placement fertilized	0.12	0.13	1.15	1.82	0.25	0.18	3.11	4.01	0.30	1.82	0.11	0.29
Placement fertilized and irrigated	0.15	0.15	1.02	2.05	0.23	0.20	3.26	5.18	0.29	1.58	0.10	0.26
Broadcast fertilized	0.13	0.14	1.19	2.05	0.22	0.20	3.07	4.49	0.30	1.65	0.10	0.31
Broadcast fertilized and irrigated	0.14	0.14	1.06	2.00	0.21	0.18	3.12	4.46	0.30	1.67	0.10	0.28
NPK fertirrigations, no basic fertilization	0.16	0.15	1.03	2.19	0.20	0.19	2.88	4.31	0.29	1.58	0.10	0.32
NPK fertirrigations, half the basic fertilization	0.16	0.13	0.96	1.75	0.23	0.19	3.20	4.68	0.30	1.86	0.09	0.25
PK placement with 3N fertirrigations	0.11	0.13	1.19	1.94	0.23	0.18	2.97	4.18	0.30	1.59	0.11	0.25
PK placement with 4N fertirrigations	0.12	0.16	1.24	2.07	0.22	0.19	3.14	4.32	0.29	1.32	0.10	0.26
Organically cultivated carrots												
Location 1	0.14	0.13	0.09	1.71	0.26	0.25	2.42	5.53	0.23	1.05	0.11	0.25
Location 2	0.11	0.15	0.10	1.63	0.33	0.39	3.05	6.65	0.28	2.20	0.13	0.31

60 kg/ha), 4.42—6.59 g/kg DM (level of fertilizer N 120 kg/ha) and 4.95—7.07 g/kg DM (level of fertilizer N 180 kg/ha). The variation at each fertilizer level is caused by differences between growing seasons. DRAGLAND (1978) published root NO_3-N contents of 1.8—5.3 g/kg DM (0—160 kg N/ha), and NILSSON (1979) reported contents of 0.5—1.2 g/kg DM (50—100 kg N/ha mineral fertilizer) and 0.5—0.9 g/kg DM (50—100 kg N/ha organic fertilizer) in roots.

In the present study, at the first sampling date the NO_3-N content in shoots was high (Fig. 1). It decreased clearly during the growing period. The NO_3-N content in roots decreased slightly during the season and at harvest the NO_3-N contents were on the same level in shoots and roots, the average content for 1985 and 1986 in roots being 0.8 g/kg DM (Fig. 1). The concentration is similar to NILSSON's (1979) results but lower than those reported by LEHTINEN (1984) and DRAGLAND (1978).

There was a clear difference between years in the NO_3-N contents of roots (Table 2). In

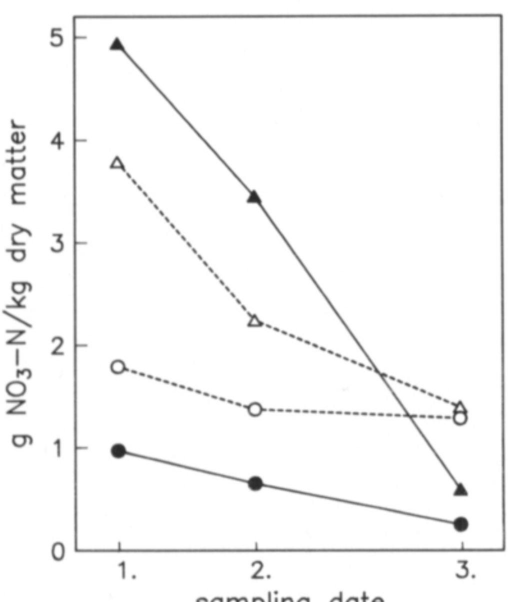


Fig. 1. The development of the NO_3-N content of roots (——●—— 1985, – –○– – 1986) and of shoots (——Δ—— 1985, – –Δ– – 1986) as the average of treatments.

1985, the NO_3-N content was lower than in 1986 at all sampling dates (Fig. 1), a result probably caused by weather conditions. In August, September and October the mean day temperature and the number of sunshine hours were higher in 1985 than in 1986 (EVERS 1988). This is in agreement with the literature. MAYNARD et al. (1976) and CORRÉ & BREIMER (1979) reported that, among other things, low temperature and low light intensity increase the NO_3-N content of plants.

In unfertilized treatment the NO_3-N content was low both in shoots and roots at all sampling dates (Fig. 2a, 2b). At harvest, a low NO_3-N content was also measured in unirrigated placement fertilized treatment, but there were no great differences between treatments (Table 2). The highest NO_3-N content, in both shoots and roots, was with NPK fertirrigations without basic fertilization (Fig. 2a, 2b). In the study of BARKER et al. (1984) with lettuce, the results clearly indicated that nitrogen fertirrigations led to a comparatively high level of NO_3 in the crop. They also found a relatively high N recovery percentage by the fertirrigated crop, especially at a lower level of N fertilization. The proportion of NO_3-N in the total N content was higher in the fertirrigated crop as compared to broadcast fertilization.

In 1986 at harvest, the fertilization did not cause a significant increase in the root NO_3-N content as compared to unfertilized treatments, but irrigation increased the root NO_3-N content significantly as compared to unirrigated treatments (Table 3). High NO_3-N content in roots was a result of NPK fertirrigations as compared to placement fertilization, broadcast fertilization, single application, unirrigated single application or PK placement with N fertirrigations (Table 3). High NO_3-N content in roots was also a result of NPK fertirrigations without basic fertilization as compared to unirrigated single application or PK placement with N fertirrigations (Table 3).

The NO_3-N content of organically cultivated carrots at three succeeding sampling dates

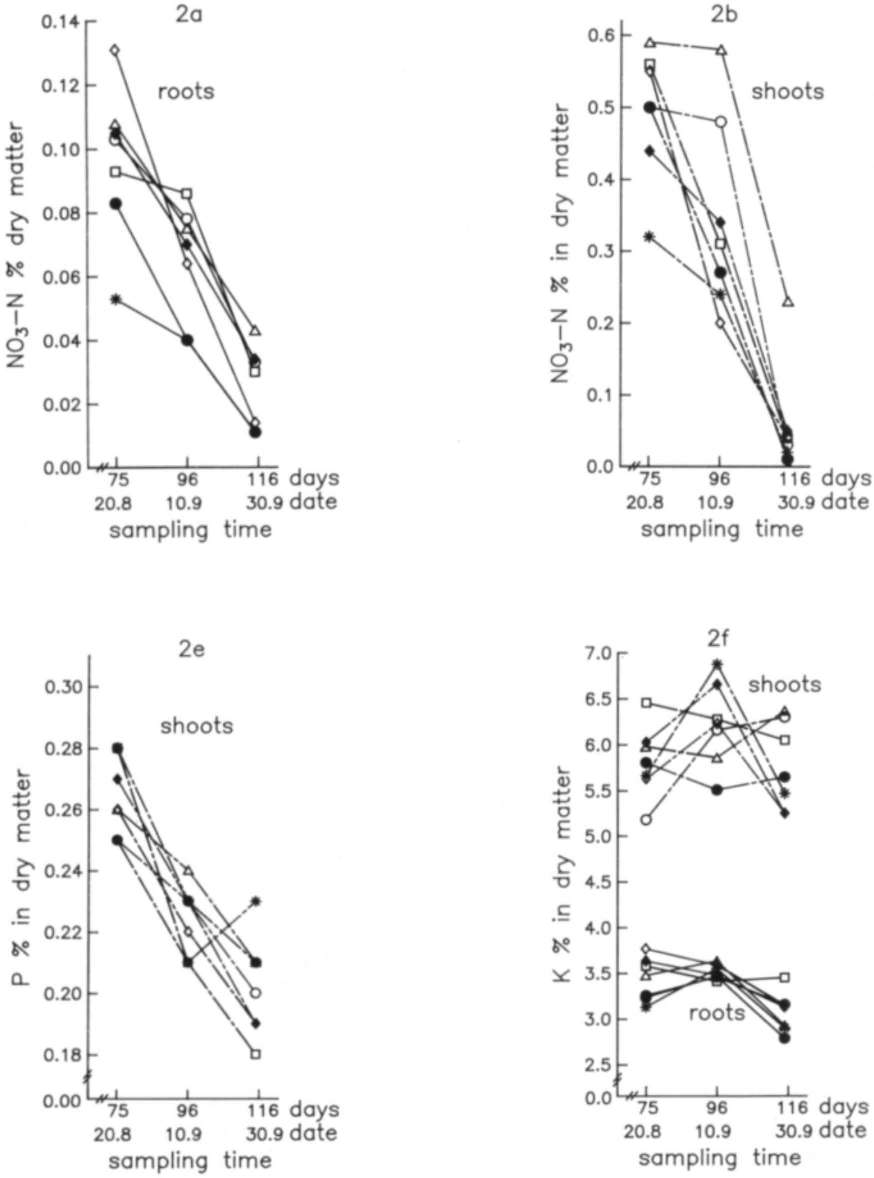
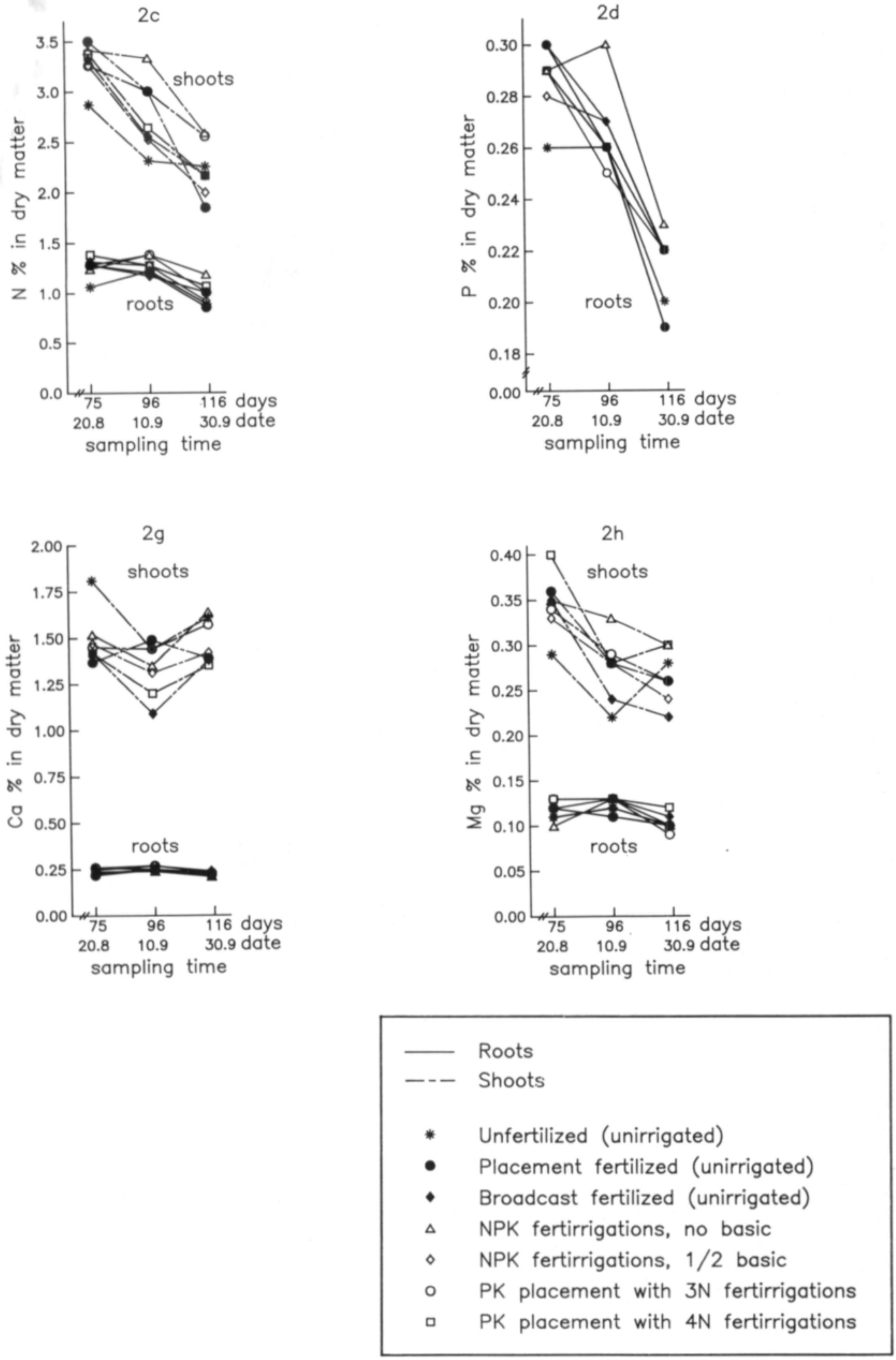


Fig. 2. The effect of different fertilization practices on the development of the NO_3-N, N, P, K, Ca and Mg contents of carrot shoots and roots (1985).



2c
N % in dry matter
shoots
roots
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
75 96 116 days
20.8 10.9 30.9 date
sampling time
2d
P % in dry matter
roots
0.00
0.18
0.20
0.22
0.24
0.26
0.28
0.30
75 96 116 days
20.8 10.9 30.9 date
sampling time
2g
Ca % in dry matter
shoots
roots
0.00
0.25
0.50
0.75
1.00
1.25
1.50
1.75
2.00
75 96 116 days
20.8 10.9 30.9 date
sampling time
2h
Mg % in dry matter
shoots
roots
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
75 96 116 days
20.8 10.9 30.9 date
sampling time
Roots
Shoots
Unfertilized (unirrigated)
Placement fertilized (unirrigated)
Broadcast fertilized (unirrigated)
NPK fertirrigations, no basic
NPK fertirrigations, 1/2 basic
PK placement with 3N fertirrigations
PK placement with 4N fertirrigations

Table 3. Contrasts and the significance of differences (* $p \leq 0.05$, ** $p \leq 0.01$, *** $p \leq 0.001$) in contrast analysis.[1] Carrot root NO_3-N, N, P, K, Ca, Mg, ash and dietary fibre content at harvest, 1986.

Contrasts		NO_3-N	P	Ash	Dietary fibre
Unfertilized	vs. Fertilized			0.004**	0.002**
Not irrigated	vs. Irrigated	0.004**	0.04*		0.006**
Normal	vs. Big amount N				
Placement fertilization	vs. Broadcast fertilization		0.04*		
Placement fertilization	vs. Split application		0.02*	0.004**	
Placement fertilization	vs. NPK fertirrigations, no basic fertilization		<0.001***		
Placement fertilization	vs. NPK fertirrigations[2]	0.03*	0.008**	0.01*	
Placement fertilization	vs. PK placement with N			0.01*	
Broadcast fertilization	vs. Split application				
Broadcast fertilization	vs. NPK fertirrigations, no basic fertilization				
Broadcast fertilization	vs. NPK fertirrigations	0.04*			
Broadcast fertilization	vs. PK placement with N				
Single application	vs. Split application			0.004**	
Single application	vs. NPK fertirrigations, no basic fertilization		0.004**		
Single application	vs. NPK fertirrigations	0.02*	0.05*	0.02*	
Single application	vs. PK placement with N			0.01*	
Irrigated single application	vs. Split application				0.009**
Irrigated single application	vs. NPK fertirrigations, no basic fertilization		0.04*		
Irrigated single application	vs. NPK fertirrigations				
Irrigated single application	vs. PK placement with N	0.05*			0.006**
Unirrigated single application	vs. Split application		0.03*	0.003**	
Unirrigated single application	vs. NPK fertirrigations, no basic fertilization	0.01*	0.001**		
Unirrigated single application	vs. NPK fertirrigations	0.003**	0.01*	0.01*	
Unirrigated single application	vs. PK placement with N			0.009**	
P and K placement fertilization	vs. P and K no placement fertilization		0.006**		
PK placement with N	vs. NPK fertirrigations, no basic fertilization	0.01*	0.01*		
PK placement with N	vs. NPK fertirrigations	0.002*			

[1] N: Fertilization increased the N content as compared to unfertilized treatments ($p = 0.004$**) and PK placement with N fertirrigations increased the N content as compared to NPK fertirrigations ($p = 0.03$*).

K: The only significant difference was in the first contrast; fertilization increased the K content ($p = 0.001$***) as compared to unfertilized treatments.

Ca and Mg: The fertilization practices did not affect the Ca and Mg contents.

[2] This contrast includes NPK fertirrigations without basic fertilization and NPK fertirrigations with half the basic fertilization.

were 1.44, 1.17 and 1.35 mg/kg DM at location 1 and 1.67, 1.62 and 1.05 mg/kg DM at location 2. At location 1, the N-amount of the compost fertilization was 113 kg/ha water-soluble N and 450 kg/ha total N. At location 2, the N amount of the compost fertilization was 47 kg/ha water-soluble N and 424 kg/ha total N (Evers 1988). The NO_3-N values are higher than those reported by Nilsson (1979). The NO_3-N content of organically cultivated carrots was on the same level with the content in the fertilizer experiment (Table 2).

Nitrogen

According to Jansson et al. (1985), the N content of plants is of special importance nutritionally, as it directly reflects their value as a source of protein. In carrot roots the nitrogen content was low, ranging between 0.75—1.25 % in dry matter, whereas the nitrogen content in spring wheat grains and pea seeds, respectively, was 2.2—3.0 and 4.0—4.5 % in dry matter (Jansson et al. 1985).

The variation in the nitrogen content of carrot roots seems to be quite systematic. In fertilizer experiments with increasing nitrogen levels, the nitrogen content increased from 1.04 to 1.45 % DM (Bishop et al. 1973), from 0.77 to 1.11 % DM (Nilsson 1979) and from 1.02 to 1.58 % DM (Lehtinen 1984). In the present study, fertilization increased the nitrogen content of roots, and nitrogen content was higher with PK placement with N fertirrigations as compared to NPK fertirrigations without basic fertilization or to NPK fertirrigations. It may be possible that the placement of phosphorus increases root growth and thus promotes nitrogen uptake (Table 2, Table 3). The nitrogen content of roots was in accordance with the literature mentioned above. In all cases the root N content tended to be approximately 50 % of the N content of the corresponding leaves (Table 2).

The nitrogen content of carrot roots decreased only slightly during the growing period, but there was a notable decrease of N content in shoots (Fig. 2c). In 1986, the N content of the organically cultivated carrot roots were equal to those of the fertilization experiment, that of the carrot shoots being lower than in the fertilizer experiment (Table 2).

Phosphorus

In the literature, the P content of carrot roots has been reported to be 0.25—0.30 % DM when grown on mineral soils (Bishop et al. 1973), 0.26—0.31 % DM (Nilsson 1979), 0.25—0.28 % DM (Lehtinen 1984) and 0.21—0.27 % DM (Jansson 1985). In the present study, the P content of carrot roots was in accordance with the literature (Table 2). In 1986 the highest P contents were observed in placement fertilized treatments, although PK placement with N fertirrigations got bigger amount of P than the placement fertilized treatments (Table 1, Table 2). There were statistically significant differences between fertilization methods in 1986 (Table 3). Placement fertilization increased P content as compared to broadcast fertilization, split application, NPK fertirrigations without basic fertilizations or NPK fertirrigations (Table 3). The placement of P and K increased the P content as compared to treatments where P and K were not placement fertilized. Single application, unirrigated or irrigated single application and PK placement with N fertirrigations increased the P content as compared to NPK fertirrigations without basic fertilization. Single application and unirrigated single application also increased the P content as compared to NPK fertirrigations (Table 3). Irrigation decreased the P content (Table 3). Organically cultivated carrot roots had a higher P content than those of the fertilizer experiment (Table 2). The P concentration in organically cultivated soils was remarkably higher than in the fertilization experiment (Evers 1988).

In the literature, the P content of carrot leaves has been reported to be 0.19—0.27 % DM on mineral soils (Bishop et al. 1973) and 0.17—0.21 % DM (Nilsson 1979). In the study of Nilsson (1979), organic fertilizer increased the P content of leaves as compared to mineral fertilizer. In the present study, the P content of carrot leaves was in accordance with the literature (Table 2). In the fertilization experiment, the P content of roots and leaves decreased during the growing period (Fig. 2d, 2e). In the organically cultivated carrot shoots, the P contents were higher than those of the fertilizer experiment (Table 2) and the NILSSON (1979) study.

Potassium

The vegetative plant parts are rich in potassium and the variation in the K content is relatively great, whereas the K content of grains is low and relatively constant (JANSSON et al. 1985). In the study of BISHOP et al. (1973), the K content of carrot shoots and roots was 3.79—5.88 % DM and 2.65—3.06 % DM, respectively. They also found that there were differences between years, particularly in the K content of roots. The variations in carrot K content have been reported to be 2.21—4.09 % DM in roots (LEHTINEN 1984), 2.76—2.93 % DM in roots and 3.81—4.21 % DM in shoots (NILSSON 1979) and 0.98—7.84 % DM in shoots (SOUTHARDS & MILLER 1962).

In the present study, the results for K content of carrot shoots and roots (Table 2) were compatible with the literature. In 1986 there were no statistically significant differences between fertilization treatments, but fertilization highly significantly increased the K content of carrot roots as compared to unfertilized treatments (Table 3). The K content of carrot shoots was higher than that of carrot roots (Fig. 2f). The K content of carrot roots decreased slightly during the growing period (Fig. 2f).

Organically cultivated carrot roots had a low K content at location 1 (Table 2). At location 2, the K content of roots was on the same level as in the fertilization experiment. The K content of carrot shoots was higher than that of the carrots in the fertilization experiment. The K concentration in organically cultivated soil at location 2 was higher than that at location 1 and in the fertilization experiment (EVERS 1988).

Calcium and magnesium

The Ca and Mg contents of carrot roots were very similar with different fertilization treatments (Table 2) and at different sampling dates (Fig. 2g, 2h). No statistically significant differences were found (Table 3), and the results were in good agreement with the literature. NILSSON (1979) reported 0.31—0.32 % Ca in DM, LEHTINEN (1984) 0.20—0.25 % Ca in DM and JANSSON et al. (1985) 0.23—0.32 % Ca in DM in carrot roots. The above-mentioned researchers, in respective order, gave the following Mg contents of carrot roots: 0.11—0.13 % DM, 0.08—0.09 % DM and 0.09—0.15 % DM.

In the present study, carrot shoots contained an average of 1.65 % Ca in DM and 0.27 % Mg in DM (Table 2). SOUTHARDS & MILLER (1962) reported remarkably higher Ca contents (3.20—3.43 % DM) in shoots. Also NILSSON (1979) reported higher Ca contents (3.25—3.77 % DM) in shoots. Further, SOUTHARDS & MILLER (1962) reported higher Mg contents (0.64—0.71 % DM), but the Mg content in the present study was similar to the values given by NILSSON (1979).

The organically cultivated carrot roots contained slightly higher Ca contents and similar Mg contents as those of the fertilization experiment. The Ca content of carrot shoots at location 2 was high; otherwise the Ca and Mg values were on the same level as in the fertilization experiment (Table 2).

Ash content

When plant material is subjected to high temperatures, all of the organic compounds decompose and are given off in the form of gases. Only the mineral elements remain in the ash. Some nitrogen may be given off in the form of ammonium or nitrogen gas. All of the

Table 4. The effect of different fertilization practices on the ash and dietary fibre contents of carrot roots (1986).

Treatment	Ash % in dry matter	Dietary fibre	
		g/100 g fresh weight	% in dry matter
Unfertilized	6.3	3.2	29.9
Unfertilized and irrigated	7.0	3.3	30.8
Placement fertilized	8.1	3.2	30.5
Placement fertilized and irrigated	9.0	3.8	37.0
Broadcast fertilized	9.1	3.5	33.0
Broadcast fertilized and irrigated	7.8	3.7	36.0
NPK fertirrigations, no basic fertilization	7.7	3.6	35.0
NPK fertirrigations, half the basic fertilization	7.3	3.5	33.5
PK placement with 3N fertirrigations	7.4	3.3	30.6
PK placement with 4N fertirrigations	7.4	3.5	33.2
$\bar{x}$	7.8	3.5	33.0
Organically cultivated carrots			
Location 1	7.0	3.3	31.3
Location 2	8.5	4.0	41.5
$\bar{x}$	7.8	3.7	36.4

other elements absorbed from the soil are present in the plant ash (Devlin 1975).

Hansen (1981) studied the chemical composition of vegetables; the ash content in the dry matter of conventionally grown carrots was 7.4—9.8 %, and 5.7—9.4 % in the dry matter of biodynamically grown carrots. For cv. Nantes Duke, Bajaj et al. (1980) reported an ash content in fresh weight of 0.49 %; this equals a calculated value of 4.63 % in dry matter.

In the present study (Table 4), the ash content was in accordance with that reported by Hansen (1981), but higher than that reported by Bajaj et al. (1980). There were significant differences in ash content between the treatments (Table 3). Fertilization increased the ash content. Placement fertilization, single application and unirrigated single application yielded a higher ash content than did split application, NPK fertirrigations or PK placement with N fertirrigations. The mean ash content, 7.8 % of dry matter was similar in the fertilization experiment and in the organically cultivated fields, but there was a considerable difference between location one and location two (Table 4).

Dietary fibre

After cereal products, vegetables and fruits are the main sources of dietary fibre (Varo et al. 1984). The importance of dietary fibre in food for human consumption is now recognized. Low dietary fibre intake predisposes the individual to the development of several lifestyle-related diseases (Spiller & Freeman 1981). In the literature, the following dietary fibre values for carrot have been published: 4.0—5.0 g/100 g fresh weight (Robertson et al. 1980), 30.9 ± 0.3 % in dry matter (Horvath-Mosonyi et al. 1983) and 2.4 g/100 g fresh weight (Varo et al. 1984). In the last-mentioned publication, the water content was also reported; it was possible to calculate that 2.4 g/100 g in fresh weight was equal to about 21.8 % in dry matter.

The dietary fibre contents in the present study (Table 4) were lower than reported by Robertson et al. (1980) but higher than those quoted by Horvath-Mosonyi et al. (1983) and Varo et al. (1984). Fertilization and irrigation increased the dietary fibre content as compared to unfertilized and unirrigated treatments, respectively. Irrigated single application increased the dietary fibre content as compared to split application and PK placement with N fertirrigations. In the organically cultivated carrots the dietary fibre content was low at location one but high at location two (Table 4).

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SELOSTUS

Eri lannoitusmenetelmien vaikutus porkkanan NO_3-N, N, P, K, Ca, Mg, tuhka- ja ravintokuitupitoisuuksiin

Aino-Maija Evers

Kemira Oy, Espoon tutkimuskeskus, Luoteisrinne 2, 02270 Espoo

Kenttäkokeissa tutkittiin eri lannoitustapojen vaikutusta porkkanan NO_3-N, N, P, K, Ca, Mg, tuhka- ja ravintokuitupitoisuuksiin. Vertailtavina lannoitustapoina olivat sijoitus- ja pintalannoitus (ilman kastelua ja kastelun kera), NPK-kastelulannoitus ilman peruslannoitusta, NPK kastelulannoitus, jossa puolet ravinteista annettiin peruslannoituksena sijoittaen, sekä lannoitustapa, jossa P ja K annettiin sijoittaen peruslannoituksena ja N kastelulannoituksena. Yhtä annostelukertaa verrattiin myös jaksotettuun annosteluun. Tuloksia tutkittiin kontrastianalyysillä.

NO_3-N-pitoisuus oli merkitsevästi korkeampi NPK-kastelulannoituksen saaneissa koejäsenissä kuin koejäsenissä, joissa P ja K annettiin peruslannoituksena sijoittaen ja N kastelulannoituksena kasvukaudella, tai koejäsenissä, joissa kaikki ravinteet annettiin yhdellä kerralla keväällä joko sijoitus- tai pintalannoituksena. Kastelu nosti porkkanoiden NO_3-N-pitoisuutta. Lannoitus kohotti porkkanoiden N-pitoisuutta. N-pitoisuus oli korkeampi koejäsenissä, jotka saivat P:n ja K:n sijoittaen keväällä ja typen kastelulannoituksena kasvukaudella, kuin NPK-kastelulannoituksen saaneissa koejäsenissä. Sijoituslannoitus lisäsi P-pitoisuutta verrattuna pintalannoitukseen ja NPK-kastelulannoitusta saaneisiin koejäseniin. P-pitoisuus oli myös korkeampi, kun ravinteet annettiin yhdellä levityskerralla, verrattuna koejäseniin, jotka saivat NPK-kastelulannoitusta. P-pitoisuus oli korkeampi koejäsenissä, joissa P ja K annettiin sijoittaen, kuin koejäsenissä, joissa P:tä ja K:ta ei annettu sijoittaen. Lannoitus lisäsi porkkanoiden K-pitoisuuksia, mutta eri lannoitustapojen välillä ei ollut merkitseviä eroja. Lannoituksella ja lannoitustavoilla ei ollut vaikutusta porkkanoiden Ca- ja Mg-pitoisuuksiin. Lannoitus lisäsi porkkanan tuhkapitoisuutta. Sijoituslannoitus, yksi levityskerta ja kastelematon yksi levityskerta lisäsivät tuhkapitoisuutta verrattuna jaksotettuun levitykseen, NPK-kastelulannoituksiin ja koejäseniin, joissa P ja K annettiin sijoituslannoituksena keväällä ja N kastelulannoituksena kasvukaudella.

Lannoitus ja kastelu lisäsivät porkkanoiden ravintokuitupitoisuutta. Ravintokuitupitoisuus oli korkeampi, kun ravinteet annettiin kerralla keväällä ja kasvukaudella kasteltiin, kuin koejäsenissä, joissa ravinteet annettiin jaksottaen.