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Effects of fertilisation and irrigation practices on yield, maturity and storability of onions

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The study aimed to establish whether a high onion yield and good storage performance could be obtained with low fertilisation rates if irrigation was applied when necessary. Two-year experiments investigated the effects of three NPK fertiliser levels (N 50, 100, 125/150 kg/ha), with and without irrigation, on yield, advancement of maturity, storage losses and shelf life. High fertilisation advanced maturity but irrigation had no effect. High fertilisation increased yield only in 1996 (5–7%), but irrigation increased the yield noticeably: by 33.5% in 1995 and 8.5% in 1996. There was no interaction between fertilisation and irrigation. The low fertilisation optimum is attributed to the mineralisation of soil nitrogen, as the soil was rich in organic matter. At the low fertilisation level, plants took up twice as much nitrogen as present in the fertiliser, and with increased fertilisation the nitrogen uptake increased markedly. The foliage nitrogen content was low, evidently as a result of late harvesting. Treatments had only a minor effect on the storage performance and shelf life of onions. The results suggest that fertilisation rates could be reduced in onion production. Irrigation during warm and dry periods is essential to achieve the maximum yield potential and does not impair the storage quality of onions.

Key words: Allium cepa, nitrogen, onions, quality, storage

Introduction

At a yield level of 30 t/ha, the recommended nitrogen (N) fertilisation for onion in Finland is 100–120 kg/ha (Soil Testing Laboratory of Finland 1997). Phosphorus (P) and potassium (K) demands are estimated on the basis of soil analysis. The development of integrated production methods aims at reducing fertiliser inputs. In the

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Table 1. Chemical properties of soil (0–30 cm).

Year	pH	Conductivity 10 x mS/cm	P mg/l	K mg/l	Ca mg/l	Mg mg/l	B mg/l	Mn mg/l
1995	6.8	0.9	25	120	1300	100	0.5	4.3
1996	7.1	1.3	44	240	2000	260	0.7	13

Table 2. Meteorological data for 1995 –96 and the average for the period 1961–90 at Piikkiö and Mietoinen (potential evaporation).

Month	Mean temperature (°C)			Precipitation (mm/month)			Potential evaporation (mm/month)		
	1995	1996	1961–90	1995	1996	19612–90	1995	1996	1961–90
May	8.6	8.5	9.5	82	64	33	88	97	112
June	17.0	12.8	14.7	58	55	38	111	112	138
July	16.0	14.5	16.4	32	138	77	124	92	125
August	15.7	17.5	15.1	105	32	82	113	96	92

experiments of Salo (1998), for example, N uptake of 120 kg/ha was sufficient for a yield exceeding 40 t/ha. Aura (1985) found no yield increase in his 4-year experiments when N rates were raised from 50 kg/ha to 100 or 150 kg/ha.

It is usually suggested that when irrigation is applied to a field, N rates should be increased to obtain the maximum gain from the irrigation (Brewster 1990a). Irrigation can, however, improve the efficiency of fertilisers (Kaila and Elonen 1970, Dragland 1975, Riekels 1977, Sørensen 1996). It is hypothesised that, in soils of normal fertility, irrigation could ensure high yields even at a low fertilisation level. The effects of fertilisation and irrigation practices on storage performance of onion have often been contradictory.

Our objective was to find out whether the fertilisation level could be reduced by optimising irrigation without a negative impact on the yield. Also of interest were the effects of fertilisation and irrigation practices on the advancement of maturity, storage performance and shelf life.

Material and methods

Experimental site

Field experiments were performed at the Agricultural Research Centre of Finland, Horticulture at Piikkiö (60°23'N, 22°30'E) in 1995 and 1996. The soil was fine sand, rich in organic matter (3 – 6% in 1995, 6 – 12% in 1996). Data on soil P, K, Ca, Mg and Mn extractable in acid ammonium acetate (pH 4.65) (Vuorinen and Mäkitie 1955), pH and electrical conductivity in water suspension, and B by the azomethine-H method (Sippola and Erviö 1977) are presented in Table 1. Meteorological data were obtained from the meteorological station of the unit (Table 2). Potential evaporation was measured at Mietoinen, 45 km from Piikkiö.

Experimental design

The experimental set-up was a split-plot design

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Table 3. Experimental factors.

Plot	1995			1996			
Main plot = irrigation (mm)							
N = non-irrigated	0			0			
I = irrigated	3 x 15 (13, 19, 26 July)			15 (6 – 7 August)			
Subplot = fertilisation							
(N-P-K, kg/ha)	at planting	30 June	sum	at planting	18 June	15 July	sum
1	50-35-70	0-0-0	50-35-70	50-35-70	0-0-0	0-0-0	50-35-70
2	75-53-105	25-0-25	100-53-130	75-53-105	25-0-25	0-0-0	100-53-130
3	100-70-140	25-0-25	125-70-165	100-70-140	25-0-25	25-0-25	150-70-190

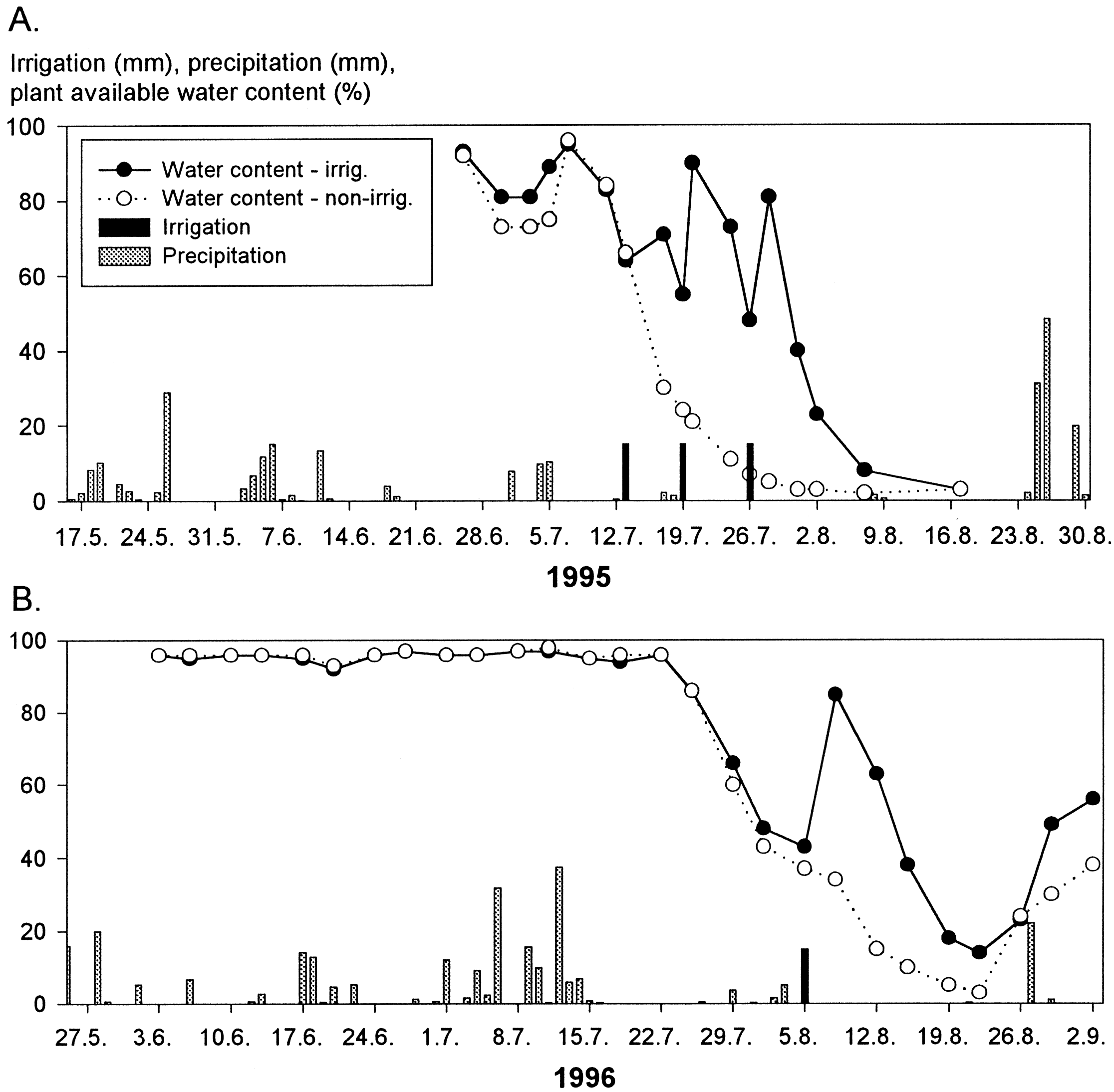

Figure 1. Precipitation, irrigation and plant-available water content in irrigated and non-irrigated plots A. in 1995 and B. in 1996.

Table 4. Development of maturity of onions.

Treatment	Onions with softened pseudostem (%)							
	1995				1996			
	25 July	28 July	2 August	8 August	15 August	19 August	22 August	29 August
N1	13	34	79	97	6	35	63	96
N2	33	55	88	100	15	33	69	96
N3	60	79	94	100	20	63	89	99
I1	20	29	66	98	10	34	57	94
I2	16	26	64	100	9	29	62	96
I3	24	52	86	98	10	36	76	98
Mean temperature (°C) between observation dates								
		16.9	20.4	16.8		18.8	19.9	17.7
Temperature sum (°C, base temp. 5°C) from planting								
	705	740	817	888	737	792	837	926
Probability								
Irrigation (I)		ns				ns		
Fertilisation (F)		0.017				0.006		
I * F		ns				ns		
Time (T)		<0.001				<0.001		
I * T		ns				ns		
F * T		0.067				0.012		
I * F * T		ns				ns		

N = non-irrigated, I = irrigated
1, 2, 3 = fertilisation levels: N 50, 100, 125/150 kg/ha

with irrigation as the main plot factor and fertilisation level as the subplot factor. The treatments were replicated in four randomised complete blocks. Details of the experimental factors are given in Table 3.

Soil water content was monitored by gypsum blocks at a depth of 15 cm, and irrigation was applied to irrigated plots when the plant-available water content fell below 50% (Fig. 1). Because it was rainy at the beginning of both growing seasons and soil water content was high, irrigation was applied only in July in 1995 (45 mm) and in August in 1996 (15 mm). Irrigation was terminated when the plants started to mature as indicated by softened pseudostem.

Fertilisation treatments included three levels of macronutrients. The highest level corresponded to the typical rate of N used by Finnish farmers, which is adjusted according to the season. Lower levels were set to 50 and 100 kg/ha N. At the lowest fertiliser level, P and K rates were in accordance with current recommendations (Soil Testing Laboratory of Finland 1997) and growth should not have been limited by either nutrient. At the lowest level, all fertilisers were applied before planting and incorporated in the soil; at the two higher levels, some of the N and K were given in one or two top dressings.

Crop management

Onion plants of cultivar Sturon were cultivated from sets transplanted by hand on 15 May 1995 and 20 May 1996. The planting density was 7.5 x 25 cm. The crop was cultivated in five-row

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beds in 1995 (444 400 plants/ha) and in four-row beds in 1996 (426 700 plants/ha). The distance between beds was 50 cm. Before planting, the sets were thermally treated at 40°C for 24 h to control downy mildew (*Peronospora destructor*) and soaked in isofenphos (Oftanol, 0.1%, Bayer) and thiophanate methyl (Topsin M, 0.2%, Kemira Agro Inc.) solution to control pests and diseases. Other plant protection and cultivation measures were in accordance with common practice.

Crops were harvested after full maturity (see Table 4) on 17 and 22 August 1995 and on 4 September 1996. There were two harvests in 1995 due to the uneven maturity in irrigated and non-irrigated plots. Since there was no difference in yield between the two harvest dates, the average yield of the two dates was used in the data analysis. The yield was measured in the three inner rows in 1995 and in all four rows in 1996. The harvested area was 4.72 m^2 in 1995 and 6.25 m^2 in 1996.

After harvest, the bulbs were dried, leaves attached, in a heated and ventilated greenhouse at 20–30°C. In 1995, the leaves were removed after drying, but in 1996, they were not removed until the storage losses of bulbs were analysed.

Observations and measurements

The development of maturity was monitored by calculating the proportion of onions with softened pseudostem. In 1995, the yield was measured as dried onions after removal of the leaves. In 1996, the yield included the weight of the dry leaves, which was 3–4% of the total weight.

In 1995, samples for dry matter and N analyses were taken after artificial drying in the greenhouse. In 1996, the samples for N analysis were taken in January from cold-stored bulbs. The bulb dry matter content was measured after additional drying at 60°C to constant weight. N in bulbs and foliage was measured by the macro-Kjeldahl method, which uses copper as a catalyst and potassium sulphate to raise the digestion temperature. After digestion, Kjeldahl-N was measured with a Kjeltec Auto 1030 Analyzer using alkaline distillation of NH_3. NH_4 was determined by acidimetric titration (Tecator 1981).

Storage

The bulbs were stored at 0–2°C. The relative humidity of the store could not be controlled. Storage losses were analysed three times (on 3–4 January, 13–14 March and 8–9 May in 1995 and on 14 January, 20 March and 21 May in 1996). Weight loss during storage was measured, and the bulbs were graded as saleable, rooted, sprouted or diseased. To evaluate their shelf life, the saleable onions were stored for a further 4 weeks at 17°C. After the test, the bulbs were once more graded as they had been after the cold storage. Shelf life was not evaluated in May 1995 as most of the onions had formed roots during cold storage.

Statistical analysis

Experimental data were analysed with a mixed model for split-plot design using the SAS MIXED procedure (Littell et al. 1996). The model included fertilisation and irrigation and their interaction as fixed factors and block, main plot and subplot errors as random factors. The effects with F-test probability values above 0.05 were considered non-significant, and probability values above 0.10 are not presented. Means of fertilisation treatments were compared by contrasts. In the data of 1995, four plots that suffered from standing water after high rainfall were treated as missing observations. Maturity and storage data were analysed by repeated measures analysis of variance, with time of analysis or storage time as the repeated factor. Data on diseased onions were not analysed statistically if only a few infected bulbs were infected. The aptness of the models was checked by residual analyses which did not indicate any cross departures from the assumptions of the models.

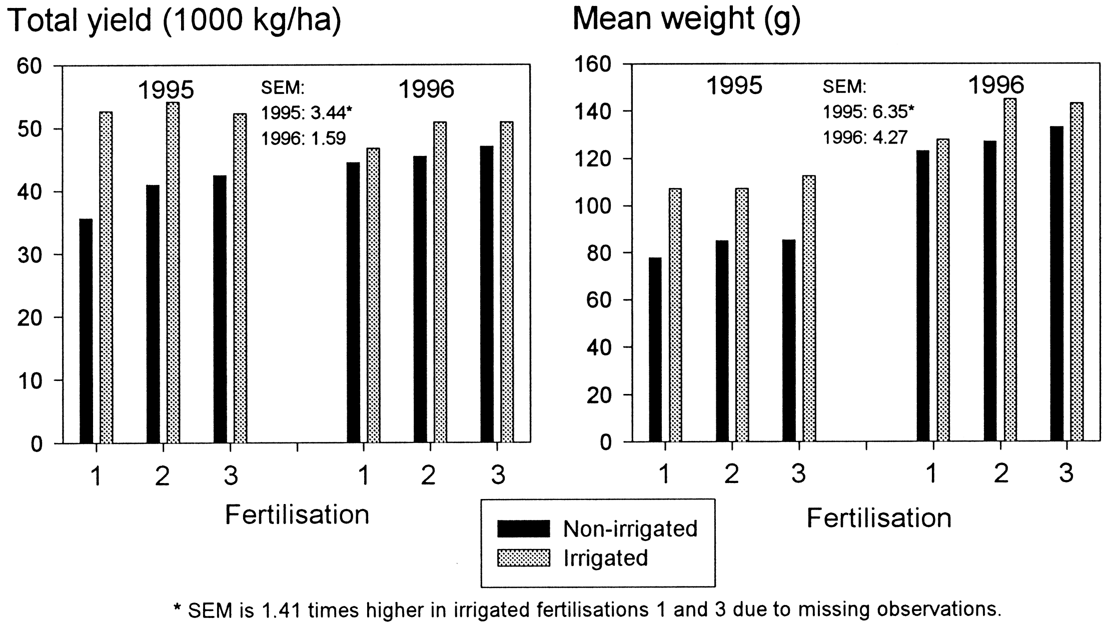

Figure 2. Total yield and bulb mean weight of onions in 1995 and 1996 at different fertilisation levels (1, 2, 3 = N 50, 100, 125/150 kg/ha). SEM = standard error of the mean.

Results

Maturity

Increased fertilisation hastened maturation, and the proportion of plants with softened pseudostem was greatest in the plots with the highest fertilisation (Table 4). Comparison of treatments by contrasts revealed no differences in maturity between the two lower fertilisation levels. Irrigation seemed to delay maturation in 1995, but the effect was not statistically significant. In both years, the air temperature during maturation was higher than the long-time average and foliar fall-over proceeded quickly (Table 4).

Yield and bulb mean weight

In 1995, the level of fertilisation had no statistically significant effect on total yield (P=0.644) or bulb mean weight (P=0.732) (Fig. 2). In 1996, higher fertilisation resulted in a slightly higher total yield per area (P=0.051) and a significantly higher bulb mean weight (P=0.026). According to contrasts, the differences were due to the lower yield and bulb mean weight of the lowest fertilisation. However, the difference between the results at highest and lowest fertilisation levels was only 3.3 t/ha (7.2%) in total yield and 13 g (10.0%) in bulb mean weight.

Irrigation increased the yield in both years, even in 1996 when the field was irrigated only once with 15 mm of water (Fig. 2). The average increase in yield due to irrigation was 13.3 t/ha in 1995 (P=0.026) and 3.9 t/ha in 1996 (P=0.032). The increase in bulb mean weight was 26 g (P=0.023) in 1995 and 11 g (P=0.047) in 1996. There were no interactions between irrigation and fertilisation in either year. Treatments had no effect on plant density: hence, the mortality was not affected by fertilisation or irrigation (data not shown).

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Plant dry matter and N uptake

Bulb dry matter content ranged between 14.6% and 15.3% in 1995 and between 14.3% and 15.6% in 1996 and was not affected by the treatments. Neither fertilisation nor irrigation had a clear effect on the N concentration of the foliage (Table 5). Irrigation and fertilisation had a more marked effect on the N content of the bulb than on that of the foliage. In both years, irrigated plants had a lower N content than non-irrigated plants. Increasing fertilisation increased the concentration.

The total N uptake increased with fertilisation and was not affected by irrigation (Table 6). Most of the N was localised in bulbs, the amount of N in foliage being only 3–5 kg/ha in 1995 and 7–9 kg/ha in 1996. In 1995, the total N uptake was, on average, 111, 140 and 165 kg/ha in fertilisations 1, 2 and 3, respectively; in 1996, the corresponding values were 93, 127 and 153 kg/ha. In 1996, there was a significant interaction between fertilisation and irrigation in bulb and total N uptake, the increase in N uptake between the two higher fertilisations being less for the irrigated than for the non-irrigated onions.

Table 5. Nitrogen content of foliage and bulb.

Treatment	Nitrogen content (% of dry matter)			
	1995		1996	
	Foliage	Bulb	Foliage	Bulb
N1	0.76	1.87	0.69	1.21
N2	0.81	2.41	0.73	1.40
N3	0.81	2.30	0.76	1.87
I1	0.86	1.57	0.75	0.93
I2	0.78	1.80	0.71	1.39
I3	0.81	2.27	0.73	1.61
Probability				
Irrigation (I)	ns	0.037	ns	0.028
Fertilisation (F)	ns	0.003	ns	<0.001
I * F	0.015	0.064	ns	0.068

N = non-irrigated, I = irrigated
1, 2, 3 = fertilisation levels: N 50, 100, 125/150 kg/ha

Storage losses

Fertilisation and irrigation practices had only minor effects on storage losses, and in 1995–96, did not influence the proportions of rooted, diseased or saleable onions. Weight loss was slight-

Table 6. Nitrogen uptake of plants.

Treatment	Nitrogen uptake (kg N/ha)					
	1995			1996		
	Foliage	Bulb	Total	Foliage	Bulb	Total
N1	4	100	104	7	92	99
N2	3	135	138	8	114	122
N3	5	147	152	9	151	161
I1	5	113	118	7	80	87
I2	4	138	141	9	124	132
I3	4	174	178	8	138	145
Probability						
Irrigation (I)	ns	ns	ns	ns	ns	ns
Fertilisation (F)	ns	0.007	0.009	0.022	<0.001	<0.001
I * F	ns	ns	ns	0.100	0.022	0.014

N = non-irrigated, I = irrigated
1, 2, 3 = fertilisation levels: N 50, 100, 125/150 kg/ha

Table 7. Storage losses in 1996–97 (weight loss: % of weight before storage, others: % of weight after storage). Percentages of saleable onions are not available for March.

Treatment	Weight loss %			Saleable onions %		Rooted onions %		
	Jan	Mar	May	Jan	May	Jan	Mar	May
N1	3.2	4.6	6.0	99	41	0	4	57
N2	2.9	4.3	5.4	100	35	0	17	65
N3	2.7	4.1	5.1	100	40	0	3	60
I1	3.3	4.4	5.6	99	57	0	0	42
I2	3.0	4.4	5.4	100	37	0	11	63
I3	2.7	4.2	5.2	100	34	0	4	66
Probability						*		
Irrigation (I)	ns			ns		ns		
Fertilisation (F)	0.007			0.003		<0.001		
I * F	ns			0.012		0.032		
Time (T)	<0.001			<0.001		0.001		
I * T	ns			ns		ns		
F * T	ns			0.001		0.054		
I * F * T	ns			0.017		ns		

* Only data for March and May included in analysis
N = non-irrigated, I = irrigated
1, 2, 3 = fertilisation levels: N 50, 100, 125/150 kg/ha

ly less for irrigated than for non-irrigated onions (P=0.087). Losses increased towards the end of storage, rising from 2.1–2.6% in January to 3.1–3.8% in March and 4.3–5.3% in May. The proportions of rooted onions were 0%, 18–33% and 36–49% in January, March and May, respectively; the rates for diseased onions were 0–1%, 2–5% and 14–20% in the same months.

In 1996–97, increased fertilisation decreased weight loss during storage (Table 7). The occurrence of storage diseases was only 0–1% in different treatments and was not analysed statistically. The major cause of losses was the formation of new roots, which was affected by fertilisation treatment. The effect of fertilisation on rooting differed with the irrigation treatments, but the rates for rooted onions were generally lowest at the lowest level of fertilisation. The proportion of saleable onions was inversely related to the proportion of rooted bulbs: in January, 99–100% of the bulbs, but in May, less than half of the bulbs, were saleable.

Shelf life

In 1995–96, there were no differences in shelf life results between treatments. Weight loss during four weeks' storage at 17°C was lower in January (2.7–3.5%) than in March (3.5–4.1%) (P_{time} =0.008). In January, none of the onions formed new roots, but in March, 5–12% of them rooted. The proportion of diseased onions was 0–2% in January and 1–6% in March (P_{time}= 0.085). Onions did not sprout during shelf-life tests.

In 1996–97, experimental factors had no direct effect on weight loss or the proportions of saleable, rooted, diseased or sprouted onions. Only a few bulbs were infected, and rooted onions were found only in the test that was started in March (14–46%). Greater weight loss was observed when the shelf-life test was started after a longer time in storage (P=0.003), but the effect of storage time was dependent on fertilisation ($P_{fert*time}$ =0.005). At the lowest fertilisa-

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tion rate, weight loss did not change much in the course of time (3.9% in January, 3.4% in March and 4.2% in May), but at the two higher rates, the increase in weight loss was larger in May (4.4%) than in January (3.4–3.5%). Towards the spring, shelf-life tests showed an increase in sprouting (P<0.001). The effect of time was dependent on fertilisation ($P_{fert*time}$=0.021): at the lowest fertilisation level, there were 9%, 9% and 28% of sprouted onions in January, March and May, respectively. At the higher levels, the percentages of sprouted onions increased with time even more: at the second level the proportions were 9%, 10% and 34% in January, March and May, and at the highest level 6%, 6% and 40%, respectively.

Discussion

Yield and maturity

Our results indicate that fertilisation rates could be reduced in Finnish onion production. In 1995, increasing the N fertilisation rate over 50 kg/ha had neither positive nor negative effects on the yield or storability of onions. In 1996, the yield increased up to the second level of fertilisation (100 kg N/ha), in which most nutrients were incorporated in soil before planting and an additional 25 kg/ha N and K was broadcast one month later, on 18 June. A further top dressing, applied on 15 July to the plants receiving the highest fertilisation, resulted in no extra benefit. The yield benefit from increasing N fertilisation from 50 to 100 kg/ha was only 5.5%.

The lowest rates of P and K were in accordance with Finnish recommendations. Since higher P and K applications had no influence on yield, the present recommendations appear to be appropriate.

The low optimum fertilisation level may have been due to active mineralisation of N in the soil. Greenwood et al. (1992) reported mineralisation rates of 0.56–1.51 kg N/ha d^{-1} from the Netherlands. Finnish soils often have a very high organic matter content and the potential for mineralisation is considerable if the soil temperature is high enough. The end of the growing period in the experimental years was warmer than the long-time average, so mineralisation presumably satisfied the N demand of onion in mid and late summer.

Irrigation had a greater impact on yield than had fertilisation rate. The favourable effect of irrigation in 1995 is attributed to prolongation of growth before foliar fall-over. Drought is known to advance maturation (Riekels 1977, Henriksen 1984, Mondal et al. 1986). Although the effect of irrigation on maturation was not statistically significant here, in 1995 the difference between irrigated and unirrigated plots was almost as great as between fertilisation levels. In 1996, irrigation had no visible or statistically significant effect on advancement of maturity since there was only one application in August.

Onion plants are sensitive to drought during maximum leaf growth in mid-season, 7–10 weeks after planting (Riley 1989), and at the time of bulb enlargement (Dragland 1975). In 1995, a dry and warm period began in the middle of July, when leaf growth was still active and bulbs were growing fast. In 1996, when rainfall satisfied plant water demand until the end of July, plants were able to form strong and large leaves, but the dry and warm weather at the beginning of August may have interfered with bulb growth. Pfülb and Zengerle (1990) emphasise that irrigation should not be stopped too early, as it is needed until bulb development is complete and the skin has started to darken.

When the weather is warm and dry, continuing irrigation in late summer could thus be a way to prolong growth and ensure maximum yield potential. If there is a risk of plants not maturing, heavy irrigation should be avoided (Riekels 1977).

Increased fertilisation accelerated maturation, but the difference in time between the lowest and highest fertilisation rates in achieving

80% softened pseudostems was only a few days. The effect of fertilisation might have been greater had the growing season been cooler. Henriksen (1987) found a 9-day delay in harvest time at 90% leaf fall-over at a fertilisation rate of 0 kg N/ha compared with that of 120 kg N/ha. Increasing the fertilisation rate to 180 kg N/ha did not promote maturity further. In the study of Sørensen (1996), onions grown at a supply rate of 65 kg N/ha showed delayed leaf fall-over relative to higher N applications.

The timing of N fertilisation is crucial: in Brewster's study (1990b) delaying N fertilisation until 2 August resulted in a significant delay in maturity compared to fertilisation before sowing. Brewster et al. (1987) found a significant positive correlation between the level of N top dressing and the percentage of thick-necked onions, and noted that under conditions favouring thick necks (cool summer, slow early growth, late maturation), high N may aggravate the problem. In unfavourable years, maturation may be incomplete in Finland. In view of these and other results, N fertilisation applied late in the growing season would seem to delay rather than hasten maturation.

Nitrogen uptake

Active mineralisation was shown in plant N uptake. The total plant uptake of N in 1995 was, on average, 111 kg/ha at the lowest fertilisation rate and 165 kg/ha at the highest rate. N uptake in 1996 was slightly lower: 93 kg/ha and 153 kg/ha at the lowest and highest fertilisations, respectively. At the lowest fertilisation, plants were therefore able to take up twice the amount of N that was given in the fertiliser. Increased fertilisation caused a marked increase in plant N uptake, although the yield was little affected. N uptakes of similar magnitude have been observed in other studies (Sørensen 1996, Salo 1998).

Irrigation decreased the bulb N content but did not influence the total plant N uptake. Thus the decline in N content may be related to the higher bulb weight in irrigated plots. The bulb dry matter content was not influenced by irrigation, which is consistent with the results of Dragland (1975) and Pfülb and Zengerle (1990).

Most of the N was localised in bulbs, and the bulb N content increased with the increase in fertilisation. The low N content of the foliage is attributed to the late timing of harvest: at the time of harvest, leaves had already partly senesced, as was shown by the foliage N content, which was lower than in the studies of Wiedenfeld (1986) and Salo (unpublished), in which analyses were made prior to senescence. Nilsson (1980) observed translocation of N from foliage to bulb during the maturation period. Translocation may have continued during artificial drying of the bulbs at 20–30°C. Despite the potential translocation, the bulb N content was similar to that found in other studies (Greenwood et al. 1980, Nilsson 1980, Salo (unpublished)).

Bulb dry matter content was not affected by the treatments, a finding that is in accordance with the results of Henriksen (1987) and Maier et al. (1990).

Storage performance

Fertilisation and irrigation had little effect on the storage performance of onions. Weight loss during storage was slightly affected, but the practical significance of the differences was negligible. These results support those of the majority of earlier studies, which showed no effect of N fertilisation (Kepka and Sypien 1971, Dragland 1975, Tahvonen 1981, Aura 1985) or irrigation (Riekels 1977, Henriksen 1984, Pfülb and Zengerle 1990) on storage losses. Some researchers report that high N supply may promote sprouting during or after cold storage (Riekels 1977, Henriksen 1984), but we did not find any such effect. Sprouting was not observed during cold storage, and in shelf life tests only in 1996–97.

Storage losses were minimal in January but increased towards the spring, mainly due to the formation of roots. In 1995–96, storage diseases (mostly *Botrytis allii*) had spoiled nearly 20%

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of the bulbs by May, but diseased bulbs amounted to only a few per cent in March. In 1996–97, bulbs were infected only occasionally.

The high incidence of rooting was probably caused by the excessively high humidity of the store. The general recommendation is that relative humidity should be kept below 70–75% to suppress rooting and rotting (Komochi 1990). We could not maintain such conditions in our experiment. Rooting was not observed in analyses in January, but later in the spring, a substantial proportion of the bulbs had been spoiled in this way.

Shelf-life tests in 1996–97 revealed rooted bulbs only in the test that was started in March. The reason for this remains a mystery as the conditions during shelf-life tests were similar. One possible explanation is that rooting did not take place in May because a large proportion of onions had already formed roots during cold storage, and those that were left for shelf-life tests were individuals not susceptible to root formation. In March, when rooting was just beginning at a low temperature, bulbs whose roots could not yet be distinguished formed roots very fast at 17°C.

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SELOSTUS

Lannoituksen ja kastelun vaikutus sipulin satoon, sadon valmistumiseen ja varastokestävyyteen

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Tutkimuksen tavoitteena oli selvittää, voidaanko määrältään ja varastokestävyydeltään hyvä sipulisato saavuttaa vähällä lannoituksella, kun kasvustoa kastellaan tarvittaessa. Kaksivuotisissa kokeissa tutkittiin kolmen lannoitusmäärän (N 50, 100, 125/150 kg/ha) ja kastelun vaikutusta sadon määrään, valmistumiseen sekä varasto- ja kauppakestävyyteen. Sadon valmistuminen nopeutui lannoitusta lisättäessä, mutta kastelu ei vaikuttanut tuleentumiseen. Runsas lannoitus lisäsi satoa vain vuonna 1996 (5–7 %). Sen sijaan kastelu lisäsi satoa selvästi: 33,5 % vuonna 1995 ja 8,5 % vuonna 1996. Kastelun ja lannoituksen välillä ei havaittu yhdysvaikutusta. Alhaisen lannoitusoptimin oletetaan johtuvan typen mineralisoitumisesta maassa. Pienimmällä lannoitustasolla kasvit pystyivät ottamaan kaksinkertaisen typpimäärän lannoituksessa annettuun määrään verrattuna. Lannoituksen lisääminen lisäsi huomattavasti kasvien typenottoa. Lehtien typpipitoisuus oli pieni, minkä oletetaan johtuvan myöhäisestä sadonkorjuusta. Käsittelyiden vaikutus sipulin varasto- tai kauppakestävyyteen oli vähäinen. Tulosten mukaan sipulin lannoitusta voidaan alentaa, jolloin ravinnepäästöt ympäristöön vähenevät. Kastelu on välttämätöntä kuivien jaksojen aikana täyden sadon saamiseksi, eikä se heikennä sipuleiden varastokestävyyttä.