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Optimum Ranges of Leaf Nitrogen for Yield, Fruit Quality, and Photosynthesis in 'BC-2 Fuji' Apple

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Abstract

The influence of five rates of ground-applied nitrogen (N) on yield, fruit quality attributes (fruit size, color, firmness, soluble solid concentrations, and starch), and leaf mineral concentrations and photosynthesis in 'BC-2 Fuji' apple [*Malus sylvestris* (L.) Mill. var. *domestica* (Borkh.) Mansf.] trees were studied to determine optimum ranges of leaf N for quality fruit and yield. Fruit skin red color decreased as the rate of N increased. Under the environmental conditions of this experiment, annual ground application of N for optimum fruit quality should be more than 31.8 g/tree/year but less than 99.8 g/tree/year, preferably about 65.8 g/tree/year. Optimum leaf N should be between 2.00% and 2.10 % dry weight (preferably about 2.05% dry weight) in a light-crop year or an "off-year" and more than 2.22% but less than 2.38% dry weight (preferably about 2.30% dry weight) in a heavy-crop year or an "on-year" for production of high quality fruit. Leaf K decreased while leaf Mg and Mn increased with increase in N application. Fall application of N often resulted in lower leaf N, thus, better fruit color. Other fruit quality attributes were not consistently affected by time of N application. Leaf net photosynthesis (Pn) decreased between mid-Jun and mid-August. Trees receiving 31.8 g N/tree/year had lower leaf Pn than those receiving higher rates of N.

Fruit quality can be affected by several preharvest orchard cultural practices, particularly N fertilizer application. Magness et al. (12) found no differences in leaf N or fruit color for 'York Imperial' and 'Delicious' fertilized in late fall or early spring. Forshey (9) reported that both amount and method of N application could affect leaf N and other minerals in 'McIntosh' apple. Neilsen et al. (15) studied the influence of three regimes of orchard vegetation management and three rates of N fertilizer on fruit quality and leaf mineral concentrations of 'Golden Delicious' apple and reported that tree N was affected more by vegetation management than by rate of N applied. Reduction in leaf N and trunk diameter and superior fruit skin color and firmness at commercial harvest occurred consistently when the orchard floor was sod (Neilsen et al. (15)). In that study, application of 180 kg $N.ha^{-1}$ increased leaf N and Mn and reduced fruit skin color and firmness at harvest as compared to lower N treatments. Meheriuk et al. (13) studied the influence of three rates of N fertilizer (30, 60 or 180 $kg.ha^{-1}$) on fruit quality and leaf mineral composition of 'Golden Delicious' and reported that higher rates of N tended to give greener fruit, higher leaf N, and lower leaf K. Fallahi et al. (3, 4, 5) reported that higher application of N increased leaf N, fruit green color and internal ethylene in 'Starkspur Golden Delicious' apple in a high-density orchard. In a recent study with 'Scarlet Gala' apple, Fallahi and Mohan (7) reported that fruit from trees that received 68 g actual N/tree/year had better color than fruits from trees with higher rates of N.

The role of nutrients on shoot leaf net photosynthesis (Pn) of apple trees has been studied. Nutrition deficiencies reduce leaf Pn of apple trees (2, 8). Kaakeh et al. (11) found that leaf Pn rates increased with increasing urea rates in 'Redchief Delicious' apple.

'Fuji' apple has gained popularity among consumers in recent years because of its pleasant taste and the ability of fruit to maintain firmness over a long period both in controlled-atmosphere and regular

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cold storages. 'Fuji' constitutes a large portion of new apple plantings in the Pacific Northwest. Limited knowledge on mineral nutrition of 'Fuji,' especially the impact of N on fruit quality, necessitates establishment of baseline information for optimal N application for maximum production of high quality fruit.

The objective of this research was to study the influence of five ground applications of N on yield, fruit quality attributes (fruit size, color, firmness, soluble solid concentrations, and starch), and leaf mineral concentrations and photosynthesis of 'BC-2 Fuji' trees to determine optimum leaf N for production of quality fruit in 'BC-2 Fuji' apple.

Materials and Methods

The experimental orchard was located at the University of Idaho Parma Research and Extension Center, Parma, Idaho, U.S.A. The orchard site was not cultivated previously and had a uniform soil profile. The soil type was a sandy loam with a pH of about 7.50.

Soil was plowed down to 61 cm prior to planting. Random soil samples indicated that no harmful nematodes were present. Uniform size (1.3-cm trunk diameter) 'BC-2 Fuji' apples on M.9 NAKBT337, M.26 EMLA, or M.7 EMLA were obtained from C & O Nursery, Inc. (Wenatchee, WA, USA) and planted at 2.74 x 5.49 m spacing on 4 April 1991. A micro-jet sprinkler system was installed with one riser per tree, located midway between every two trees. The orchard was irrigated based on monitoring soil moisture with water sensors.

A trellis system was installed and bamboo poles were used to support trees. Trees were topped at 71 cm from the ground after planting. The central leader was bent in June of every year in a "zigzag" pattern. Lateral branches were bent with strings and fastened to the main trunk at about 55° angle from vertical to induce flower bud initiation.

Zinc-50 (a Zn-containing compound with 50% zinc) was sprayed in the late dormant season (late March) every year at a concentration of about 3.1 g/liter to runoff. A 1.52-m herbicide strip was maintained along the tree rows. Other cultural practices in this experimental orchard were similar to those used in commercial apple orchards.

The native soil of this orchard was very low in nitrogen (N), and the annual N release through mineralization was only about 3 g per tree. Therefore, 48 g of actual N per tree (as urea) was applied to all trees in a 60 cm radius around the trunk on 10 July 1991 (about three months after planting). Experimental N treatments started in 1992. Five rates of N as urea (46% actual N) were applied on the ground in a circle about 61 cm (during 1992 and 1993), 76 cm (during 1994) and 91 cm (during 1995 through 1998) from the trunk of the trees in either spring or fall. For spring application, each of the five rates of N was split in half. One half was applied at full bloom, and the second half was applied in about the middle of June. For fall application, the total amount of each level of N was applied in early October of each year. In 1992, 27.2 g, 77.1 g, 127.0 g, 176.9, or 226.8 g actual N per tree per year was applied. In 1993 through 1998, 31.8 g, 99.8 g, 167.8 g., 235.9 g, or 303.9 g of actual N per tree per year was applied. Since 1996, in a side-test, an additional treatment was added in which each tree received total of 65.8 g actual N/tree/year in two equal splits in spring. The 65.8 g N/tree/year treatment was half way between 31.8 and 99.8 g N/tree/year treatments. Prior to 1996, trees with the 65.8 g N/tree/year treatment received total of 31.8 g actual N/year/tree in two equal splits in spring. Data was analyzed with and without this treatment to investigate the precise effect of 65.8 g N/tree/year. In this report, only results without the 65.8 g treatment are presented, while results with inclusion of this treatment are discussed in the results and discussion section.

Experimental design was a split-split plot complete randomized design with three rootstocks as main plots and five rates of ground applied N as sub-plots and two times of application (spring and fall) as sub-sub plots with four two-tree plots per replication (block).

Thirty-four fruit from each tree were picked randomly at commercial harvest time (between 17 to 20 Oct.) 1994 through 1998. Fruit were divided into two groups, weighed, and placed in perforated polyethylene bags. Fruit from one bag were tested for various quality attributes at harvest. The second bag of fruit was stored at –1°C with about 90% relative humidity for five months and then evaluated for quality.

Fruit color was rated visually on a scale of 1 = 20% pinkish-red progressively to 5=100% pinkish-red. Fruit firmness was measured at harvest and after storage on three peeled sides of each fruit by a penetrometer (Facchini, Alfonsine, Italy). These fruits then were cut equatorially. One wedge from the calyx-end half of every fruit was juiced, and the soluble solids concentration (SSC) was measured by placing three to four drops of juice on a hand held, temperature-compensated refractometer (Atago N1, Tokyo, Japan) both at harvest and after storage. Stem-end half of the fruit at harvest was dipped in I-KI solution and the starch degradation pattern (SDP) for each fruit was recorded by comparison with the SDP standard chart developed for apples. In this procedure, immature fruit have a SDP of 1.2 and very mature fruit have a SDP of 6.0. Only results of fruit quality attributes at harvest time are reported here.

Thirty leaves per tree were sampled randomly from the middle of the current-season's shoot in mid-August of 1993 through 1998. Leaves were washed in a mild Liquinox detergent solution, rinsed with distilled water, and dried in a forced-air oven at 65 °C. Leaves were weighed before and after drying, and percent dry weight was calculated. Dried leaves were ground to passed a 40-mesh screen, and analyzed for N by the micro-Kjeldahl method (16) and for potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), and copper (Cu) by dry ashing at 500 °C, digestion, and atomic absorption spectrophotometery (Perkin-Elmer B1100, Norwalk, CT, USA) as described by Chaplin and Dixon (1) and Jones (10).

In 1998, three spurs and three current-year-grown shoots per tree were tagged, and photosynthesis of one leaf per shoot or per spur were measured, using a LI-COR 6200 Portable Photosynthesis System (LI-COR, Lincoln, Nebraska, U.S.A.) in mid-June, mid-July, and mid-August.

Assumption of normality was checked by computing univariate analysis for all tree responses in this study. Analyses of variance were conducted by using SAS (SAS Institute, Cary, NC, USA), and means were compared by least significant difference (LSD) at $P \leq 0.05$. Since no major interaction between rootstock and N rate was observed in this study, only effects of different rates of N are reported here.

Results and Discussion

Yield, and Fruit Quality Attributes: Years 1993, 1995, and 1997 were light-crop years or "off years", while 1994, 1996, and 1998 were heavy-crop years or "on-years" (Table 1). Yield per tree and fruit size were not consistently affected by various rates of N applications. However, trees receiving 31.8 g N /tree/year tended to have smaller fruit in 1994 and 1997 and tended to have lower yield after trees reached full production in 1997 (Table 1). Fruit from trees that received 31.8 g N/tree/year tended to be firmer than those from other treatments in 1994, 1996, and 1997 (Table 1). Fruit from trees receiving 31.8 g N/tree/year always had better fruit color than those from other treatments from 1994 through 1998 (Table 1). Fruit red color decreased with every incremental increase in N application (Table 1). A color rating of above 3.5 is considered as commercially desirable. In 1995 and 1997 (off-years), fruit from trees receiving 99.8 g N/tree/year had color ratings above 3.5, and these ratings were statistically similar to fruit color ratings from trees with 31.8 g N/tree/year (Table 1). However, during "on-years" of 1994, 1996, and 1998, the fruit color ratings in the 99.8 g N/tree/year

Table 1. The effect of different rates of nitrogen on yield and fruit quality at harvest time in 'BC-2 Fuji' apple over several years.[z]

N/tree/year (g)	Yield (kg/tree)					Fruit weight (g)				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
31.8	8.4 ab	2.0 ab	43.3 ab	13.7 b	56.6 a	270.3 b	220.2 b	214.3 a	268.0 c	201.7ab
99.8	10.5 a	1.5 b	45.1 ab	22.3 a	59.7 a	288.6 a	218.4 b	217.8 a	279.6 bc	201.4 ab
167.8	10.1 ab	1.4 b	47.8 ab	15.7 b	59.4 a	295.1 a	242.4 ab	214.4 a	301.6 a	203.5 ab
235.9	7.7 b	2.4 a	49.9 a	14.8 b	60.1 a	288.2 a	248.2 a	218.3 a	300.7 a	195.5 b
303.9	8.1 ab	2.0 ab	40.7 b	12.3 b	58.1 a	280.9 ab	249.0 a	216.7 a	297.6 ab	206.4 a
	Firmness (Newton)					Color (1-5)[y]				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
31.8	81.8 a	90.4 a	77.7 a	79.9 a	73.4 a	3.48 a	4.27 a	3.74 a	3.98 a	3.40 a
99.8	78.0 b	90.9 a	74.8 bc	75.4 b	72.6 a	2.96 b	3.99 ab	3.08 b	3.62 ab	2.90 b
167.8	77.3 b	87.9 ab	75.4 b	74.5 b	75.2 a	2.73 b	3.79 bc	2.77 c	3.43 bc	2.71 b
235.9	79.0 ab	85.3 b	74.1 bc	75.2 b	71.9 a	2.90 b	3.57 cd	2.57 cd	3.26 cd	2.72 b
303.9	78.8 ab	83.8 b	73.5 c	73.7 b	73.8 a	2.45 c	3.40 d	2.32 d	2.93 d	2.67 b
	Sugar (°Brix)					Starch Degradation Pattern (SDP)[y]				
	1994	1995	1996	1997	1998	1994	1995	1996	1997	1998
31.8	14.7 b	15.4 c	14.1 b	15.2 b	14.1 c	3.68 a	3.44 a	5.03 a	3.87 b	5.31 a
99.8	14.9 ab	15.7 bc	14.3 ab	15.3 ab	14.2 bc	3.75 a	3.25 a	5.08 a	4.06 ab	5.35 a
167.8	15.3 a	16.4 a	14.6 ab	15.3 ab	14.5 ab	3.79 a	3.33 a	5.03 a	4.30 a	5.33 a
235.9	15.0x ab	16.1 ab	14.6 ab	15.7 a	14.4 abc	3.77 a	3.33 a	5.00 a	4.14 ab	5.29 a
303.9	15.1 ab	16.2 ab	14.7 a	15.4 ab	14.7 a	3.72 a	3.46 a	5.08 a	4.34 a	5.25 a

[z]Mean separated within columns by LSD at $P \leq 0.05$.
[y]Color rating: 1 = green progressively to 5 = uniformly red. SDP: Least SDP = 1.2, Highest SDP = 6.0.

treatment were below 3.5. Therefore, application of 99.8 g N/tree/year is excessive for optimum fruit color in some years, particularly when trees have heavy crop. Fruits from trees with 31.8 g N/tree/year always had lower SSC than those with higher quantities of N, and the differences were sometimes significant (Table 1). Fruit from trees with 31.8 g N/tree/year had slightly lower SDP in 1997 (Table 1). Other than this case, no difference was observed in SDP of fruit from different quantities of N application (Table 1). Fruit respiration and internal ethylene increased as N application rates increased (data not shown), which is in agreement with previous reports (5, 6).

Trees that received N in fall often had about 4% better fruit red color than those which received N in spring, due to their lower leaf N (data not shown). Time of N application did not consistently affect other fruit quality attributes.

Relationship Between Leaf N and Crop Load and Fruit Quality: Leaf mineral concentrations changed with N rates and crop load. Leaf N was lower in a light-crop-year (off-year) than in a heavy-crop-year (on-year) (Tables 1 and 2). Trees with 31.8 g N/tree/year often had significantly lower leaf N than those with higher rates of N (Table 2). Many of the fruit quality attributes, particularly fruit red color, were adversely affected when rate of N application per tree was at, or exceeded 99.8 g N/tree/year (Table 1). Thus, it seems that under conditions of this experiment, annual N application should be more than 31.8 but less than 99.8 g /tree/year in 'Fuji' apple trees. Obviously, soil N varies from place to place, and thus, determination of leaf N provides a better tool for judging fruit quality than does the rate of N application. Considering yield and fruit quality attributes, we conclude that the optimum leaf N range for fruit quality in 'BC-2 Fuji' apple in a light-crop year or an "off-year" is different from the range in a heavy-crop year or an "on-year". The optimum leaf N range for high fruit quality in light-crop years or "off-years" should be between 2.00% (average of leaf N values for 31.8 g N/tree/year treatment during light-crop years of 1993, 1995, and 1997) and 2.10% dry weight (average of leaf N values for the 99.8 g N/tree/year treatment during light-crop years of 1993, 1995, and 1997). Leaf N optimum range for high fruit quality during heavy-crop years or "on-years" should be more than 2.22% (average of leaf N values for the 31.8 g N/tree/year treatment during on-years of 1994, 1996, and 1998) but less than 2.38% dry weight (average N values of 99.8 g N/tree/year during on-years of 1994, 1996, and 1998) (Tables 1 and 2).

All values of leaf N, yield, and fruit quality attributes in the trees that received 65.8 g actual N/tree/year treatment were in a "midway position" between the values for the 31.8 and 99.8 g N/tree/year treatments (data not shown). Fruit from the 65.8 g N/tree/year treatment had commercially high pack-out grade and quality (data not shown). Therefore, application of 65.8 g N/tree/year should be considered as "the ideal amount of actual N" for obtaining high quality fruit and optimum yield in 'Fuji' apples under tree spacing and other conditions of our experiment. Therefore, the "ideal single point" for leaf N in an "off-year" was about 2.05% dry weight (2.00% dry weight + 2.10% dry weight/2) and in an "on-year" was about 2.30% dry weight (2.22% dry weight + 2.38% dry weight/2) for optimum yield and high fruit quality. However, adjustment perhaps needs to be made when the tree spacing is closer than the spacing used in this experiment. Based on the 2.74 x 5.49-m spacing of this study, there were 664 trees per hectare in our experimental orchard, and application of 65.8 g actual N/tree/year provided 43.69 kg actual N/ha/year. Since N was applied in a 91-cm-radius from the trunk after 1994, we suspect that even if the in-row tree spacing was as close as 182 cm (91 cm radius x 2 adjacent trees = 182 cm) and between row spacing was kept at 5.49 m, still the rate of 65.8 g actual N/tree/year could be applied. In that case, there would have been 996 trees per hectare and the total actual N application would have been 65.53 $kg.ha^{-1}$.

Table 2. The effect of various rates of nitrogen on leaf minerals over several years and on shoot leaf photosynthesis (Pn) in 1998 in 'BC-2 Fuji' apple.[z]

N/tree/year (g)	N (% dry wt)						K (% dry wt)				
	1993	1994	1995	1996	1997	1998	1993	1994	1995	1996	1997
31.8	2.09 c	2.20 c	1.88 b	2.17 d	2.03 c	2.28 d	1.96 a	1.54 a	2.07 a	1.59 a	2.00 a
99.8	2.18 bc	2.39 b	1.97 b	2.30 c	2.14 b	2.44 c	1.79 b	1.37 c	1.87 b	1.45 b	1.92 a
167.8	2.10 c	2.44 ab	2.10 a	2.38 b	2.20 ab	2.50 bc	1.74 bc	1.41 bc	1.79 bc	1.42 bc	1.88 a
235.9	2.29 ab	2.47 a	2.18 a	2.42 b	2.28 a	2.53 b	1.67 c	1.41 bc	1.74 cd	1.36 c	1.98 a
303.9	2.35 a	2.47 a	2.20 a	2.49 a	2.26 a	2.59 a	1.70 c	1.49 ab	1.70 d	1.44 bc	1.90 a

	Ca (% dry wt)					Mg (% dry wt)				
	1993	1994	1995	1996	1997	1993	1994	1995	1996	1997
31.8	0.98 b	1.35 b	1.19 ab	1.44 b	1.07 ab	0.24 b	0.28 c	0.23 c	0.28 d	0.25 d
99.8	1.06 ab	1.50 a	1.24 a	1.53 a	1.14 a	0.24 b	0.30 b	0.24 bc	0.32 c	0.27 cd
167.8	1.07 ab	1.44 ab	1.16 b	1.47 b	1.11 ab	0.24 b	0.30 b	0.25 abc	0.34 b	0.28 bc
235.9	1.12 a	1.45 ab	1.22 ab	1.49 ab	1.03 b	0.27 a	0.31 b	0.26 ab	0.36 a	0.31 a
303.9	1.13 a	1.39 ab	1.19 ab	1.46 b	1.08 ab	0.26 ab	0.33 a	0.27 a	0.36 a	0.30 ab

	Cu (μg·g⁻¹)					Mn (μg·g⁻¹)					Leaf Pn (μmol.m⁻².s⁻¹)		
	1993	1994	1995	1996	1997	1993	1994	1995	1996	1997	June	July	August
31.8	9.4 a	9.8 a	9.9 a	9.4 ab	10.7 a	51 c	58 e	38 d	53 d	53 d	12.7 b	7.3 a	6.2 b
99.8	8.7 b	9.6 a	9.3 ab	9.5 ab	10.5 ab	59 c	76 d	47 d	68 cd	59 d	13.2 ab	8.9 a	9.8 a
167.8	8.6 b	9.7 a	8.6 b	9.5 ab	9.7 bc	66 c	90 c	62 c	81 c	73 c	13.7 ab	8.4 a	7.0 b
235.9	8.7 b	9.5 a	8.9 b	9.1 b	10.0 abc	95 b	129 b	94 b	126 b	93 b	13.9 a	8.5 a	7.9 b
303.9	8.5 b	9.6 a	8.9 b	9.9 a	9.3 c	118 a	149 a	111 a	149 a	106 a	—	—	—

[z]Mean separated within columns by LSD at $P \leq 0.05$.

Stiles (17) reported that desirable ranges of leaf N for mature-bearing trees were about 9% lower than those for young-bearing trees in 'Golden Delicious,' non-spur 'Delicious,' and 'McIntosh' apples. In our study, we observed more year-to-year fluctuations in leaf N due to crop load rather than bearing age of the trees (Tables 1 and 2). However, both crop load and tree age should be taken into account when interpreting leaf N analysis in 'Fuji' apple.

Trees that received N in fall often had about 3% lower leaf N than those received N during spring.

Other Leaf Minerals: Leaf K declined but leaf Mg increased as rate of N applications increased (Table 2), which is in agreement with a previous experiment with 'Starkspur Golden Delicious' apple (3). Competition between NH_4^+ and K^+ in the soil (14) could have resulted in a lower uptake of K in the high N treatments. Potassium and Mg are antagonistic elements; therefore, the reduction of K uptake perhaps resulted in an increase in leaf Mg. Leaf Mn increased with every incremental increase in N application (Table 2). Nitrogen did not affect leaf Fe (data not shown). Other than leaf N, time of application did show consistent effect of other leaf minerals (data not shown).

Leaf Photosynthesis: Net photosynthesis (Pn) in most treatments decreased between June and July or August (Table 2). Shoot leaves had higher Pn than spur leaves (data not shown). Shoot leaves of trees receiving the lowest level of N (31.8 g N/tree/year) had the lowest rates of Pn at all times, but the differences were not always significant (Table 2). Net photosynthesis increased with N application up to 99.8 g N/tree/year. Addition of N greater than 99.8 g N/year/tree did not increase Pn. More research is needed to determine optimum ranges of leaf N for Pn and crop load in 'Fuji' apple.

General Comments: No major interactions were observed between rootstock, rate of nitrogen or time of N application in this study.

We would like to emphasize that tree fruit nutrition, especially under high-density systems, is a very complex issue. Rootstock, soil physics and chemistry, water availability, temperature, and several other factors interact and influence mineral uptake and fruit quality, and all of these factors should be tested for nutrition management in a higher density system than our experimental orchard.

Conclusions

Under the environmental conditions of this experiment, ground application of N for optimum fruit quality should be more than 31.8 g but less than 99.8 g/tree/year, preferably about 65.8 g N/tree/year. Considering yield and fruit quality attributes, optimum leaf N should be somewhere between about 2.00% and 2.10% dry weight, preferably 2.05% dry weight, in a light-crop year or an "off-year" and more than 2.22% but less than 2.38% dry weight, preferably 2.30% dry weight in a heavy-crop year or an "on-year" for production of high quality 'Fuji' fruit. Application of N at or higher than 99.8 g N/tree/year (leaf N levels at or higher than 2.10% or 2.38 % leaf N, in an "off-year" and an "on year", respectively) can adversely affect fruit color and firmness, and this adverse effect is more evident during high-crop years ("on-years") than "off-years". Leaf K declines while leaf Mg and Mn increase with increase in N application. Leaf Pn decreased between mid-June and mid-July or mid-August. Trees receiving 31.8 g N/tree/year had lower leaf Pn than those receiving higher rates of N.

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Winter Cover of Strawberry

The study was conducted in two continental and two coastal experiments on field-grown strawberries on high beds. It was shown that use of winter cover reduced freezing injury in plants without snow cover during winter. Cover positively affected development of flower stalks, increasing the number and the proportion of flower stalks that were large. Also, it reduced injury in flower primordia and thus the number of misshapen fruits and made the plants produce larger fruits. As a sum, these effects increased the yield up to 9% in the continental and 45% in the coastal fields. The yield differences of the coastal vs. the continental experiments were partly due to more freezing and thawing at the coastal than at the continental fields, and partly influenced by a snow roof to keep the snow off the plants in the continental experiments. Generally, covering with fleece, bubble plastic and brown-paper-laminated bubble plastic gave a better result than straw for winter covering. When straw was used it was essential to remove it in early spring. Using fleece and bubble plastic as winter covers, there was no difference in yield by removal of cover in the first week of April or May for the cvs 'Bounty' and 'Senga Sengana' but cv. 'Korona' reacted generally positively to prolonging the covering period. Covering from 1 September to 1 November only, had a negative effect on yield compared with no cover, while covering April only was equal to no covering. From: Nestby et al. 2000. J. Hort. Sci. & Biotech 75(1):119-125.